THE NICKEL BULLETIN

A SUMMARY OF CURRENT INFORMATION ON NICKEL

DECEMBER, 1951

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Standard Methods of Chemical Analysis: Summary Information

SOC. PUBLIC ANALYSTS AND OTHER ANALYTICAL CHEMISTS: 'Bibliography of Standard Tentative and Recommended or Recognized Methods of Analysis.' *Published by W. Heffer and Sons, Ltd., Cambridge*, 1951; 222 pp. Price 25/-.

In 1945 the Society of Public Analysts and Other Analytical Chemists, recognizing the need for correlation of information on standard or recognized methods of analysis, appointed a committee to examine this matter. As a preliminary step, a tabulated bibliography has been prepared, in order to indicate, *inter alia*, the subjects on which further work is required for provision of reliable analytical procedures.

The present publication contains the bibliographies so far compiled, classified in sections covering a wide range of materials, non-metallic and metallic. Each bibliography has been prepared by one or more specialists in the particular field concerned: the names of the individual contributors are given.

Only British and American authorities have been used in compilation of the bibliographies, and it is believed that the information given may later be amplified as a result of comments on this first edition. The procedures to which reference is made are graded as '*s*' (more or less standard), '*t*' (tentative), and '*r*' (recommended or recognized methods in which the compilers consider that confidence can be placed).

Section I.A.ii (compilation dated 1948) covers cast iron, steel, wrought iron and ferro-alloys, also non-ferrous metals and alloys, dealt with in the following categories: aluminium and its alloys, brasses and bronzes, copper, electrical-heating and -resistance alloys, lead and lead-base alloys, magnesium and its alloys, nickel and its alloys, solders, tin and tin-base alloys, rare metals, white metals, zinc and its alloys. Some general procedures for analysis of metallic materials are also given, e.g., estimation of oxygen, spectrographic analysis, sampling procedure, physical and mechanical testing methods.

For analysis of Monel, Inconel, nickel and nickel alloys the reference given is to 'Methods of Analysis for Principal Constituents and Qualitative Identification of some Common White Metals and Alloys', published by The International Nickel Co., Inc., 1946. For chemical analysis of nickel the method recommended is that given in A.S.T.M. Methods of Chemical Analysis of Metals, 1950, pp. 196-211.

Influence of Surface Condition of Steel on Spot-Test Results

See abstract on p. 251.

NICKEL

Canadian Production of Nickel in 1950

H. MCLEOD: 'Statistical Review of Canada's Mining Industry, 1950.' *Canad. Mining and Metallurgical Bull.*, 1951, No. 473, Sept., pp. 621-7. (*Trans. Canad. Inst. Mining and Metallurgical Engineers*, 1951, vol. 54, pp. 399-405).

The review includes graphs and tabular data relating to total mineral production, and statistics for the following individual metals: zinc, lead, copper, nickel, aluminium, gold, steel. Production of asbestos, Portland cement, coal and petroleum is also considered.

The chart relating to nickel shows production figures from 1898 onwards. It indicates a peak in 1943, when output was 144,000 tons. The 1950 figure was 15 per cent. lower, but was 9 per cent. above that for 1939.

Recrystallization of Cold-Rolled Nickel

G. W. WENSCH: 'The Recrystallization and Coalescence of Cold-Rolled Nickel.' *Univ. Microfilms, Publn.* 1563, 1950; 146 pp.

Announced, as available in microfilm or in paper enlargement, in *Chemical Abstracts*, 1951, vol. 45, July 10, p. 5590.

'Whiskers' on Metal Surfaces

See abstract on p. 273.

Determination of Nickel in High-Alloy Steels

S. HARRISON: 'The Determination of Nickel in Highly Alloyed Steels.' *Metallurgia*, 1951, vol. 44, Oct., p. 217.

A brief note is given on a paper contributed to the Fifth Annual Chemists' Conference, organized by the British Iron and Steel Research Association in October last.

The work described was designed to extend the methods covered by B.S. 1121: Part 6 (Nickel in Permanent-Magnet Alloys). The investigations now reported had special reference to the interference of copper and cobalt.

Work on the use of the sodium salt of dimethylglyoxime has made possible the formulation of the conditions required for complete precipitation of nickel in presence of copper. These are an excess of reagent (a triple amount) and a closely controlled temperature (90°C.).

Study of precipitation of nickel in presence of cobalt indicates that a method might be developed involving precipitation at 90°C., using an excess of hydrogen

peroxide, and that this would probably be effective if the cobalt content did not exceed 0·15 g.

Other papers presented at the same conference (*ibid.*, pp. 213-218) dealt with spectrographic analysis of low-alloy steels, determination of gases in iron and steel, determination of molybdenum in low-alloy steels, the conflicting behaviour of molybdenum, tungsten and vanadium in absorptiometric analysis, and the disposal of pickle liquor. All but the final paper were concerned with some aspects of the work for which B.I.S.R.A.'s Methods of Analysis Committee is responsible.

Influence of Surface Condition of Steel on Spot-Test Results

E. H. SNYDER and A. H. KLEIN: 'Chemical Spot Tests for Nickel and Molybdenum.' *Metal Progress*, 1951, vol. 60, Sept., pp. 78-9.

The writers report the observation that in spot tests on steels of various types specimens having scaled and shot-blasted surfaces tend to give erroneously high results for nickel and molybdenum. Typical examples are tabulated. It is postulated that scaling during heating for rolling or forging, or during heat-treatment, causes preferential oxidation of iron, while the less-readily-oxidizable alloy elements diffuse ahead of the oxidizing iron, giving an alloy-rich layer immediately under the scale. This layer is removed much more slowly by shot-blasting than by grinding or filing.

Procedures used for detection of the two elements are described below:—

'Molybdenum

Solution No. 1	
Distilled water	25 ml.
Conc. nitric acid	20 ml.
85% phosphoric acid	5 ml.
Solution No. 2	
10% hydrochloric acid	
Solution No. 3	
Stannous chloride	25 g.
Conc. hydrochloric acid	35 ml.

Dilute to 100 ml. with distilled water, add a few pieces of metallic tin. Keep in a dark bottle.

Solution No. 4	
Sodium thiocyanate	5 g.
Distilled water	95 ml.

Two drops of No. 1 are placed on the cleaned metal surface, followed, a short time later, by one drop of No. 2. When reaction seems complete a drop of the solution is transferred, with a glass stirring rod, to a piece of filter paper. One drop of No. 3 is placed on the spot, followed by one drop of No. 4. The formation of an orange halo round the spot indicates the presence of molybdenum. The size and depth of coloration increase with increase in concentration of molybdenum.

Nickel

Solution No. 1	
Distilled water	400 ml.
Conc. nitric acid	300 ml.
85% phosphoric acid	350 ml.
Solution No. 2	
Dimethylglyoxime	1 g.
Glacial acetic acid	60 ml.
Ammonium hydroxide	30 ml.
Ammonium acetate	10 g.

One or two drops of No. 1 are placed on the cleaned metal surface. When bubbling practically stops a small piece of filter paper is placed on the spot and a drop of No. 2 is added to the wet spot in the filter paper. Formation of a red colour indicates the presence of nickel. It is faint pink for 0·20 per cent. nickel, to bright red for 2·0 per cent. or more. If the spot remains white the amount of nickel present is likely to be well under 0·20 per cent.'

Determination of Nickel with Alpha-Furildioxime

S. A. REED and C. V. BANKS: The Determination of Palladium and Nickel with Alpha-Furildioxime.' *U.S. Atomic Energy Commission, Report AECD* 1819; declassified Mar. 9, 1948.

The report is mainly concerned with use of this reagent for determination of palladium, but since reports of earlier investigations with nickel had been found to be conflicting, the application of alpha-furildioxime for the estimation of nickel was also studied. A detailed account is given of method of preparation of the reagent, and its physical properties, and procedure for determination of both palladium and nickel is described.

Alpha-furildioxime was found to be more sensitive than dimethylglyoxime as a qualitative reagent for both palladium and nickel. Under optimum conditions 1 part of nickel was easily detected in 6,000,000 parts of an aqueous solution, and 1 part of palladium in 20,000,000 parts of an aqueous solution.

This reagent proved to be satisfactory for the quantitative precipitation of palladium, serving to separate it from nickel, platinum, cobalt, iron and many other metals, by a single precipitation from strong mineral-acid solutions. The palladium alpha-furildioxime precipitate may be dried and weighed, or may be ignited to the metal.

Although alpha-furildioxime quantitatively precipitates nickel also, its use as a reagent for this metal is precluded by the fact that the composition of the nickel alpha-furildioxime complex varies with the pH of the solution from which it is precipitated.

Nickel Containers for Benzyl Chloride

'Nickel in Benzyl Chloride Transport.' *Chemical Trade Jnl.*, 1951, vol. 129, Oct. 26, p. 983.

An American chemical company has recently put into commission a 2,400-gallon tank of nickel, for transport of pure benzyl chloride between two of its plants. Prior to introduction of this type of container the benzyl chloride required re-processing before use at the second plant.

Nickel in Enamelling

J. H. HEALEY and A. I. ANDREWS: 'The Elements of the Third, Fourth and Fifth Series as Possible Adherence-Promoting Materials for Sheet-Iron Enamels.' *Jnl. Amer. Ceramic Soc.*, 1951, vol. 34, July, pp. 214-19.

This review, prepared in the Department of Ceramic Engineering, University of Illinois, was made as a sequel to an extensive investigation of the function

of cobalt oxide in promoting adherence in sheet-iron ground-coat enamels. The aim of the review was to determine the extent to which other elements would be capable of acting in the same sense. The authors consider, *seriatim*, each of the properties which would be likely to affect adherence. The characteristics reviewed are: heat of formation, melting point, vapour pressure, atomic radius, unit-cell dimensions, hydrogen stability. Relevant data are tabulated for the elements of the groups under consideration and for their oxides.

Later sections of the paper contain a detailed critical discussion of cobalt, molybdenum, and nickel, from the standpoint of the above properties, and a classification of the elements of the third, fourth and fifth series, with reference to their position in the Periodic System and the nature and behaviour of their respective oxides. The final section contains a brief note on possible transition between the glassy structure and the metal.

Nickel in Rubber Processing

J. J. VERBANC: 'Nickel Compounds in Rubber Compounding.' *Chemical Trade Jnl.*, 1951, vol. 129, Oct. 12, p. 866.

In a paper presented at the Diamond Jubilee meeting of the American Chemical Society, the author reported the discovery, in the laboratories of Du Pont Company, of the fact that nickel salts of xanthates and dithiocarbamates, especially nickel dibutyldithiocarbamate, retard the rate of oxygen absorption by unvulcanized general-purpose synthetic rubber, and increase resistance to cracking of vulcanisates of such rubbers when exposed to ozone. Limitations of the application of the discovery lie in the green colour of the material and the fact that it has an adverse effect when compounded with natural rubber.

ELECTRODEPOSITION AND OTHER COATING METHODS

Occlusion of Hydrogen in Electrodeposited Nickel

N. THON, D. G. KELEMEN and L. YANG: 'Porosity of Electrodeposited Metals. X. Hydrogen Content of Electrodeposited Metals.' *Plating*, 1951, vol. 38, Oct., pp. 1055-8.
Report issued under the aegis of A.E.S. Research Project No. 6.

In search for factors which may be related to differences observed in gas-permeability (both initial permeability and that developed on exposure) in electrodeposited foils, a study was made of the amounts of hydrogen occluded in different metals electrodeposited under a variety of conditions. The report gives an account of experiments on foils of nickel, copper, chromium and iron.

The determinations were made partly on films stripped from a mechanically-polished stainless-steel base, and partly on deposits left to adhere on copper, after blank experiments had shown the base metal to be free from detectable amounts of hydrogen. Full details of experimental technique are given.

Nickel films were electrodeposited from the following types of bath:—

(1) Watts bath
$NiSO_4.6H_2O$ .. .. .. 330 g./L.
$NiCl_2.6H_2O$ .. .. .. 45 g./L.
H_3BO_3 .. .. 30 g./L.

(2) Chloride bath
$NiCl_2.6H_2O$ .. .. .. 300 g./L.
H_3BO_3 .. .. 30 g./L.

(3) Sulphate bath
$NiSO_4.6H_2O$ .. .. .. 300 g./L.
H_3BO_3 .. .. 30 g./L.

(4) Watts bath + 1% by wt. of nickel benzene meta-disulphonate.

(5) Watts bath + 0·1% by wt. of sodium naphthalene-1, 5 disulphonate.

(6) Watts bath + 0·1% by wt. of sodium 1-naphthylamine-4, 8-disulphonate.

(7) Watts bath + 0·1% by wt. of sodium 1-naphthylamine-3, 6, 8-trisulphonate.

The definitely lower hydrogen content observed in chloride nickel, as compared with Watts and with sulphate nickel, is well beyond experimental uncertainty and is reproducible under identical conditions. It parallels the slower development of gas-permeability porosity in chloride-nickel films, as compared with rates observed for the other types. The four organic addition compounds listed above, all of which produce deposits of high lustre, reduce the amount of hydrogen taken up, through discharge of the hydrogen ions of the bath. This effect is considered to be clearly attributable to adsorptive competition between hydrogen atoms and molecules of the organic compound. It had been shown in the earlier report that these four compounds enhance both the initial permeability and the corrosion-developed porosity of electrodeposited nickel foils, and it is considered reasonable to correlate that effect with adsorptive occlusion of these compounds in the deposit. In the absence of such adsorbable extraneous substances, hydrogen, obligatorily taken up from the aqueous solution, plays the rôle of 'foreign body'. High amounts of it are known also to produce lustre and stresses, i.e., effects similar to those produced by a variety of adsorbable organic addition agents.

With regard to the influence of variations in conditions of deposition, it was found that lowering the operating temperature favours occlusion of hydrogen, especially in chloride-nickel films; a slight lessening of the amount occluded with rising pH was observed at a value of 5·0. It was also found that deposits produced from baths which have been operated for a long time contained smaller amounts of hydrogen than those deposited from fresh solutions.

Parallelism between hydrogen content and tendency to porosity repeated itself in deposits produced on different base metals.

Discrepancies between the authors' results and (higher) hydrogen values obtained by the National Bureau of Standards, on thicker electrodeposited nickel films, are explained on the basis of difference in thickness. It has been found that the hydrogen content of electrolytic nickel decreases with increase in thickness of

deposit: this variation, integrated over a total thickness of about 2 mm., can easily result in considerably lower mean-hydrogen-content values for thick deposits. The gradient of hydrogen content across the thickness of the deposit accounts for the well-known stress and curling-up phenomena.

If, as is believed by the authors, a lower hydrogen content (in the absence of other adsorbable extraneous matter) parallels a lesser tendency to porosity, a thicker deposit will be more resistant to corrosion, not only due to its greater thickness, but also as a result of its lower hydrogen content at a greater distance from the basis-metal surface. This conclusion was qualitatively confirmed in corrosion tests.

In experiments with electrodeposited films of other metals:—

No hydrogen was detected in copper deposited from acid sulphate solutions, but cyanide copper retained very small amounts of hydrogen.

Chromium, electrodeposited in a thin layer on copper sheet, showed a very high hydrogen content.

Iron deposited from a warm chloride solution showed high hydrogen contents in thin layers (of the order of 0·0004 in.) but a 0·004 in. foil showed substantially lower hydrogen.

On the basis of their experiments, the authors conclude that hydrogen can exist in a metal in at least three forms: the *highly labile supersaturated-solution form*, the *co-H form* (co-deposited hydrogen, meaning the hydrogen taken up and retained by the deposit in course of deposition), and the *in-H form* (hydrogen taken up by the ready-made metal foil through subsequent cathodic charging with hydrogen in an appropriate electrolyte). Considerations based on facts and theories of strain-hardening of metals, and on changes of sharpness of X-ray diffraction lines (to be reported later) lead to the conclusion that hydrogen occluded in the latter two forms is located, in atomic form, along lattice dislocations.

Purification of Plating Solutions: Summary Reference Data

C. E. NAYLOR: 'Purification of Plating Solutions by Low Current-Density Electrolysis.' *Plating Notes*, 1951, vol. 3, June, pp. 77-90.

This review, prepared in the Defence Research Laboratories, Maribyrnong, Victoria, Australia, includes a summary of important published information on this subject, with some comments on the effects of impurities in various types of plating solution, and recommendations on purification methods.

Sources of metallic contaminants are listed, the essential principles of low-current-density plating-out are given, and a review is made of points which require consideration in securing successful operation of the method.

A particularly useful feature of the paper is a series of tables summarizing recommendations which have been made in the literature. These cover, respectively, removal of zinc, copper, lead, iron, cadmium and chromium from nickel baths; removal of lead, tin, nickel and cadmium from cyanide-copper baths; removal of copper, tin, lead, nickel, cadmium, silver and cobalt from cyanide-zinc baths, and removal of various metals from cadmium baths. The effects of the respective contaminants are also summarized in the tables, with some indication of the concentrations at which their deleterious influence will become obvious.

Purification of Plating Solutions: Recommended Procedure

'A Method of Removal of Organic Impurities from a Watts-Type Nickel-Plating Solution.' *New Zealand Electrical Jnl.*, 1951, vol. 24, Aug. 25, p. 674.

Note prepared by Electroplating Group, Defence Research Laboratories, Maribyrnong, Victoria, Australia.

The method, reported to be in use at the above laboratories, consists in adding potassium permanganate, dissolved in water, to oxidize the organic matter, and absorbing part of it on the resulting precipitated manganese dioxide. The amount of potassium permanganate required is determined by titrating standard potassium-permanganate solution against a small volume of nickel solution at the pre-selected temperature of treatment, to obtain a permanent faint pink colour.

'*Method*

Transfer solution to suitable tank, and reduce pH to value just below pH 3, by means of sulphuric-acid addition. Raise temperature of bath: for suitable ranges, see table below.

'Add to the solution sufficient potassium permanganate to obtain a faint pink colour, which persists throughout the treatment. For this purpose 0·25 g. per litre (or 2·5 lb. per 100 gallons) is adequate, but if contamination is severe, up to ten times this amount may be necessary.

'Duration of treatment is regulated by temperature of the solution: the following table gives a guide:—

Temperature		Time Required
°C.	°F.	
20	68	6 to 8 days*
35	95	2 days*
50	120	16 hours†
60	140	4 hours†
80	180	2 hours†
100	212	½ hour†

*Without air agitation. †With air agitation.

'Air agitation (using air free from oil) or mechanical stirring should be used.

'The precipitate should be allowed to settle overnight, and the supernatant clear solution can then be filtered into a clean tank.

'Finely divided kieselguhr, stirred into the solution (10-50 lb. per 100 gallons) may be used as a carrier for the precipitated manganese dioxide. Activated carbon may also be used, but it should not be too

finely divided, in order to obviate risk of introducing colloidal carbon. Glass wool makes a satisfactory filtering medium.

'The pH of the solution is re-adjusted by addition of freshly precipitated nickel hydroxide or nickel carbonate. Any purple coloration persisting in the filtered solution may be removed by addition of hydrogen peroxide, with care not to add excess.'

Gases in Electrodeposited Nickel

E. S. IOFFE and A. L. ROTINYAN: 'Gases in Electrolytic Nickel.' *Doklady Akad. Nauk S.S.S.R.*, 1951, vol. 77, pp. 91-2; *Chemical Abstracts*, 1951, vol. 45, p. 6089.

'Hydrogen found occluded in electrodeposited nickel is attributed solely to adsorption of organic matter from the electrolyte in the course of deposition. Proof is supplied by simultaneous analyses for carbon, hydrogen and oxygen, in various electrolytic nickel deposits. It is shown that both the hydrogen and the oxygen contents are directly proportional to the carbon content of the metal. Thus, with 0·02, 0·05 and 0·08 per cent. carbon in the deposit, the hydrogen contents (in vol. hydrogen at 20 per cent. by volume of nickel) are approximately 4, 7·5 and 11, and the oxygen contents in the same units are 2, 4·5 and 7. There is, however, a certain hydrogen content even at carbon = 0 (at 20 per cent., about 2 vol. hydrogen/vol. nickel), which is evidently of inorganic origin. The oxygen content at carbon = 0 is, however, zero, i.e., all the oxygen occluded originates in adsorption of organic matter.'

Influence of Form of Anode on Uniformity of Electrodeposited Coatings

D. MOJERT: 'Influence of Anode Form on Uniformity of Electrodeposited Nickel Coatings.' *Metall*, 1951, vol. 5, Sept., pp. 388-92.

In connexion with investigations of the degree of uniformity obtained in large-scale nickel plating of sheet material, experiments were made with anodes of various shapes:—

Solid: 400 × 500 mm., thickness 6 mm.

Perforated: same size as the solid anodes, but having holes of 6 mm. diameter at 6 mm. intervals.

Lattice-type, consisting of oval nickel rods 6/10 mm. in diameter and 520 mm. long. The rods were fastened together to form a lattice anode having the greater diameter of the rod in the plane of the lattice. The average space between the single 'strands' of the lattice was 20 mm.

The material of the anodes was, in all cases, pure nickel, and conditions of deposition were held constant, and therefore comparable, for all runs of plating. A commercial type of plating solution was used.

Determination was made of the thickness of nickel deposited at various positions on the steel cathodes. The apparatus used for removal of the coatings from the base, and the details of the measurements made, are recorded in the paper. It is shown that uniformity of deposit on sheet cathodes is much improved by the use of perforated or lattice-type anodes.

A complementary series of tests was carried out to ascertain the effect of the form of cathode on uniformity of coating. Runs were made using solid anodes for deposition on perforated sheet. By determination of the amount of nickel deposited on various parts of the cathode, it was shown that the uniformity of coating so deposited was markedly superior to that produced by depositing with a solid anode on a solid cathode. The improvement is attributed to the free access afforded by the holes in the perforated cathode. It was also established that perforated and lattice-type anodes will carry higher current densities than solid anodes, thus permitting appreciable saving in the times required for plating, and resultant economy.

Specification for Nickel Plating of Aluminium, Steel and Copper

MINISTRY OF SUPPLY: 'Process Specification for Electroplating of Aluminium, Steel and Copper with Silver and Nickel.' *D.T.D. Specification 919A*, July, 1951.

The specification covers the plating of mild steel; copper, brass, bronze and copper-nickel alloys; aluminium-base wrought materials containing specified maximum percentages of manganese, magnesium, copper and silicon.

Thickness Requirements

Basis Metal or Alloy	Minimum Total Thickness of Coatings	Minimum Thickness of Nickel
Aluminium	0·0015 in. Local	0·0004 in. Local
Steel	0·0008 in. Local 0·0004 in. Average for barrel-plated parts	0·0004 in. Local 0·0002 in. Average for barrel-plated parts
Copper, etc.	—	0·0003 in. Local or, for barrel-plated parts, average

Note 1.—Local thickness should apply only to areas that may be touched by a one-inch ball.

Note 2.—For threaded parts, of not more than ¼-in. nominal size, the final dimensions after plating shall not exceed the specified maximum for the part.

Sections of the schedule cover, respectively, pretreatment, finish plating, heat-treatment of aluminium-base materials, inspection (visual methods, adhesion tests, soldering test, tests for thickness of coating, and humidity test).

Appendices contain details of methods which may be used to give satisfactory coatings on aluminium-rich materials, and of procedure for silver plating from two types of bath. Nickel plating may be done by any standard method. Particulars are also given of the B.N.F. jet test, to be used for determination of thickness of coating, and of the conditions to be observed in humidity testing.

Bart 'Lectroclad' Process for Internal Nickel Plating of Pipe

'Pipe: Plating Process Saves Nickel.' *Iron Age*, 1951, vol. 168, Oct. 4, p. 180.

Draws attention to the advantages of the Bart process, by which the internal surface of piping can be coated with a uniform and adherent coating of nickel, 0·007 to 0·030 in. thick. The plating is claimed to become 'almost an integral part of the pipe' and the coated piping can be heated, bent, formed and subjected to other fabricating processes without risk of peeling.

The first large-scale application of Bart 'Lectroclad' piping was made in an installation at the Oak Ridge Plant of the Atomic Energy Commission, some six years ago. In spite of constant work under corrosive conditions it is still in good condition. Such piping has also been successfully used for oil-well casing, in paper-making plant, and in other branches of the chemical-engineering industry where corrosion attack is present. Further applications are in cooling coils for carrying brackish water, and in lines transporting black liquor, caustics, alkalis and fatty acids.

Production of Patina on Nickel and Nickel Alloys

W. G. SCHNEIDER: 'Quick Patina on Copper, Brass or Nickel Alloys.' *Metal Progress*, 1951, vol. 60, Sept., pp. 74-6.

The writer discusses the attractive colouring effects which result from formation of patina films under natural atmospheric conditions, and points out the desirability of producing a coating of this type on metal objects before putting them into service, thus obviating delay in obtaining the effect, and also minimizing the difference between old and new sections in repaired parts.

He gives the following details of methods for forming patina films which will protect the underlying metal and which, depending on local atmospheric conditions, will quickly change to the stable coating which would ultimately be formed after long-time exposure to such atmospheres.

For brass, commercial bronze, or other copper alloys which have an appreciable zinc content, an aqueous solution containing 1 lb. per gallon of commercial cupric nitrate is recommended. For copper or low-zinc copper-base alloys a solution containing 0·75 lb. of commercial cupric nitrate with 0·25 lb. of zinc nitrate, in 1 gallon of water, should be used: addition of zinc nitrate is not, however, essential for treatment of copper. It is noted that commercial nitrate has been found to give better results than the technical grade.

The metal should be heated to about 230°F. (110°C.) and certainly not above 275°F. (135°C.), and maintained at that temperature while the solution is being applied: otherwise an uneven coating will be obtained. Several coatings may be given, to obtain the required colour effect.

After the formation of the patina the metal may be washed in a solution containing 4 oz. of sodium hydroxide per gallon of water. A blue colour will result, the depth of which will depend on the length of time the material is left in the bath. The normal period is about 15 minutes.

It is noted that the above procedure is satisfactory also for patina coating of nickel and Monel, but that the treatment of these materials requires special care because they tend to overheat, resulting in black discoloration.

It is claimed that the films formed by the methods described inhibit corrosion in the period between installation and the final conversion of the surface to the patina stable under the service conditions.

NON-FERROUS ALLOYS

U.S. Standard Specifications for Nickel and Nickel Alloys

N. E. WOLDMAN: 'Non-Ferrous Alloy Specifications.' *Iron Age*, 1951, vol. 168, Oct. 4, pp. 240-55.

Correlation of U.S. specifications for non-ferrous metals and alloys issued by the following standardizing bodies: the American Society for Testing Materials, the Society of Automotive Engineers (A.M.S. Specifications), the U.S. Air Force, Army and Navy, and the U.S. Federal Specifications Board. The tables give a generalized description of the products by types, condition, and form: for full particulars of chemical composition, properties, tolerances, etc., the individual specifications must be consulted.

An insert supplement to these lists contains correlation of comparable U.S. arc-welding electrodes made by various firms in U.S.A. and Canada.

Young's Modulus of Nickel-Copper Alloys

T. FUKUROI and Y. SHIBUYA: 'The Measurement of the Young's Modulus of Metals and Alloys by an Interferometric Method. I. The Young's Modulus of Ni-Cu Alloys.' *Science Reports, Research Inst., Tôhoku Univ., Series A*, 1950, vol. 2, No. 5, pp. 748-57.

The apparatus described in the paper is similar to that used by CUTHBERTSON (*Jnl. Scientific Instruments*, 1937, vol. 14, p. 268), with the exception of minor modifications introduced to permit use at low temperatures. An account is also given of a device developed for elimination of mechanical vibrations.

A study of Young's modulus of nickel-copper alloys was made over the whole range: the results are compared with those which have been reported by other investigators, and reasons for discrepancies are discussed.

Bending of Nickel Silver Switch Elements

'Method of Eliminating Fractures in Bending Nickel Silver Alloy.' *Machinery (N.Y.)*, 1951, vol. 58, Sept., p. 193.

A problem encountered in metal-working shops is fracturing at bends of strip and sheet metal cold-headed to temper suitable for spring applications. In most cases bends are at approximately 90 degrees, and the forming tool is knife-edged, practically without radius.

In the works of Riverside Metal Company, Riverside,

N.J., nickel silver switch elements are made from an alloy containing copper 55, nickel 18, zinc 27, per cent. The temper is extra-hard, corresponding to a tensile strength of 102,000-115,000 p.s.i. (45·5-51·5 tons per sq. in.). The blanking direction of the part was 45 degrees relative to the direction of rolling, and the part was bent at 90 degrees, using a knife-edged tool.

Formation without fracture, retaining the same direction of blanking and using the same tools, is now accomplished by employing a 0·005-in. radius at the bend. A 45 degree angle as a blanking direction is not considered advisable, since the bending properties decrease very rapidly at this point: best forming properties are, as is known, obtained by forming in the direction of rolling. A blanking direction of 30-35 degrees has been found to provide the best combination of economy and of forming and spring properties.

Sigma in Chromium-Cobalt-Nickel and Chromium-Nickel-Molybdenum Alloys

See abstract on p. 263.

Nickel-Aluminium Alloys

L. N. GUSEVA: 'Nature of the Beta Phase of the Nickel-Aluminium System; Structure of Alloys of Nickel with Aluminium in the Beta-Phase Region at High Temperatures.' *Doklady Akad. Nauk S.S.S.R.*, 1951, vol. 77, Mar. 21, pp. 415-18; Apr. 1, pp. 615-16.

In the first investigation the β phase (NiAl) was studied by X-ray analysis, at room temperature, 600° and 900°C., and by electrical-resistance measurements. The maximum value of the lattice constant occurred at about 49 at. per cent. nickel: an ordered structure was present at all temperatures.

The second paper reports X-ray studies indicating that alloys containing 60-66·6 per cent. nickel, quenched from 1340°C., consist of a single phase (Ni_3Al_2), although two phases ($\beta+\alpha$) are formed on annealing.

Nickel-containing Materials in the Engineering Field

See abstract on p. 261.

NICKEL-IRON ALLOYS

Influence of Pressing and Fritting on Magnetic Properties of Nickel-Iron Powders

L. WEIL: 'The Coercive Field of Ferro-Nickel Powders: Effect of Compression and of Fritting.' *Jnl. de Physique et le Radium*, 1951, vol. 12, Apr., pp. 520-6.

The author reports a study of the coercive magnetic field of iron-nickel compacts containing more than 50 per cent. of nickel, paying particular attention to the influence of the proportion of voids in the agglomerated masses. The range of temperature covered was 300° to −193°C.

It was found that at room temperature magnetic anisotropy disappears in the region of 68 per cent. nickel, and for the 68 per cent. alloy it is nil at all temperatures down to −190°C. Magnetostriction vanishes at about 81 per cent. nickel.

In agreement with Néel's theory, the author's results show that masses characterized by feeble magnetic anisotropy have a coercive force proportional to the voids present, and that the limit of the coercive field for isolated grains is proportional to the magnetization. Both laws apply only to agglomerates which have been subjected to preliminary fritting and heating at 300°C. For masses which have not been heated the coercive field in almost all cases obeys the laws established by Néel for cases in which anisotropy of form controls magnetic rotation.

The author explains certain anomalies observed in the behaviour of heated agglomerates by assuming formation of Bloch boundaries at the surfaces of contacting grains, taking into account Brownian motion at such positions.

CAST IRON

Structural Phenomena in Magnesium-treated Cast Irons

R. P. DUNPHY and W. S. PELLINI: 'Nodule Genesis and Growth in Magnesium-treated Hypo-Eutectic Irons.' *Mémoires du Congrès International de Fonderie, Bruxelles*, Sept., 1951, pp. 13-23.

The authors report research carried out in the Naval Research Laboratory, Washington, D.C. The course of solidification of hypo-eutectic cast irons containing graphite in flake, spheroidal and quasi-flake forms was followed by means of cooling curves determined on 2-in. dia. bars cast in sand. A knowledge of the solidification characteristics of flake-graphite irons is presumed, but structural development in each of the magnesium-treated irons was studied by examination of the microstructures of 1-in. dia. specimens cast in insulated moulds, and quenched in water from ten temperatures representing various regions of the cooling curve. A single specimen of a hyper-eutectic iron containing spheroidal graphite was investigated in the same way.

The cooling curves of the magnesium-containing irons were characterized by eutectic arrests at temperatures lower than those for flake-graphite irons of corresponding types. In the magnesium-treated irons the number of graphite spheroids formed was found to rise rapidly at first and afterwards to remain constant during solidification. The graphite particles of flake and quasi-flake type, on the other hand, increased continuously during solidification.

It is tentatively concluded that in hypo-eutectic irons quasi-flake graphite is formed by continuous nucleation from the liquid or from previously formed eutectic carbides, whereas spheroidal graphite in such irons is probably precipitated from super-saturated hyper-eutectic liquid which occurs near to the arms of the primary austenite dendrites, during the interval in which formation of flake graphite would have occurred if the iron had not been magnesium-treated. This

process is not completed, and the last liquid to solidify does so as the iron/iron-carbide eutectic, which rapidly malleablizes during cooling, the graphite being precipitated upon the spheroids already present.

British Foundry Experience in Production of Spheroidal-Graphite Cast Iron

N. CROFT: 'Quantity Production of Spheroidal-Graphite Cast Iron.'* *Mémoires du Congrès International de Fonderie, Bruxelles*, Sept., 1951, pp. 25-35.

The Official Exchange Paper from the Institute of British Foundrymen to the International Foundry Congress reports the experiences of Lloyds (Burton), Ltd., in manufacture of spheroidal-graphite (magnesium-treated) cast iron, under licence from The Mond Nickel Company, Ltd.

The early stages of production, characterized by supply of prototype castings in small numbers for trial purposes, has been quickly followed by development on a large-scale repetition basis. The author describes the cupola furnaces used, and the nature of the charges and methods of treatment used, including special slag-disposal procedure evolved by this foundry.

The addition alloy is the nickel-magnesium type, which has been found to be the most efficient and reliable composition, and the most economical for treatment of iron from the acid-lined cupolas used. Gating and feeding methods are illustrated. It is stated that castings in the spheroidal-graphite iron strip from the mould more cleanly than flake-graphite irons of comparable composition. Fluidity is found to be entirely satisfactory and no difficulty is experienced in producing thin castings.

Full-annealing treatment comprises holding for periods up to 4 hours at 850°-900°C., followed by 4-12 hours at about 700°C. Castings which have been normalized, and those which are not otherwise heat-treated, are stress-relief annealed at 500°C.

Results reported for iron in regular production over a 9-month period demonstrate the regularity of properties obtained in large-scale manufacture. The castings made during this period have ranged from a few ounces to $\frac{3}{4}$ ton in weight, and from $\frac{1}{4}$ in. to 8 in. in thickness.

Foundry Production in Italy of Castings in Spheroidal-Graphite Cast Irons

F. CANTI and C. GALLETTO: 'A Year of Practical Experience in the Production of Spheroidal-Graphite Cast Iron.' *Mémoires du Congrès International de Fonderie, Bruxelles*, Sept., 1951, pp. 385-93.

This paper records results of a year's production of spheroidal-graphite cast iron in an Italian foundry making a wide variety of castings, ranging from 2 oz. to 25 tons in weight. Nickel-magnesium alloy is used as the addition material: trials with copper-magnesium alloy are reported to have given inferior results.

The properties guaranteed in regular production for as-cast irons are minimum tensile strength 35 tons per sq. in., with up to 2 per cent. elongation. In annealed material, minimum tensile strength of 27 tons per sq. in., with 12 per cent. elongation, is obtained.

The paper includes illustrations of typical castings in regular supply, e.g., various components of machine tools, textile machines and electrical equipment; gear wheels, brake drums, brick-press plates, and switchgear parts.

Fluidity Tests on Cast Iron

E. R. EVANS: 'The Fluidity of Molten Cast Iron.' *Brit. Cast Iron Research Assocn. Jnl. of Research and Development*, 1951, vol. 4, Oct., pp. 86-139; *B.C.I.R.A. Research Rept.* 319.

This report contains a comprehensive survey of the factors which affect fluidity, and gives a detailed account of work carried out by the British Cast Iron Research Association to determine their relative effects in cast irons of various types.

Preliminary tests were made to evaluate the form of fluidity test-piece most suitable for experimental work; a modified form of spiral-type test finally adopted is described and illustrated. This gives results which are believed to be independent of variations in mould conditions.

The relative effects of carbon, silicon and phosphorus, on the fluidity and solidification temperature of various irons, were studied, and it was found that improvements in fluidity were accompanied by decreases in temperature of solidification. The fluidity of the irons was related to the carbon-equivalent value calculated from the formula $CE = T.C. + \frac{Si + P}{3}$ and a new carbon-equivalent value based on fluidity (CEF) was evolved which was calculated from the formula

$$CEF = T.C. \frac{Si}{3} + \frac{P}{2}$$

A further section of the investigation covered determination of the effects, on fluidity, of pouring temperature, and of the following elements: manganese, sulphur, nickel, copper, chromium, molybdenum, titanium, vanadium, zirconium, aluminium, tellurium, boron, cerium, and magnesium.

Field tests made in four foundries gave satisfactory agreement with the conclusions drawn from laboratory tests. The author describes a fluidity test piece of modified design which is considered to be suitable for use in routine foundry production.

Self-Hardening Spheroidal-Graphite Cast Irons

M. BALLAY, R. CHAVY and J. GRILLIAT: 'A Study of Some Self-Hardening Spheroidal-Graphite Alloy Cast Irons.'* *Mémoires du Congrès International de Fonderie, Bruxelles*, Sept., 1951, pp. 325-38.

Properties of normal grades of cast iron are compared with those obtainable by quench-and-temper treatments, and attention is drawn to the fact that spheroidal-graphite irons are especially suitable for such treatment, since they show less tendency than

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flake-graphite irons to the formation of quenching cracks.

It is pointed out that self-hardening cast irons may be used in various ways:—

(1) in some compositions the irons are machinable as cast, and after machining may be hardened by heating, followed by air cooling;

(2) with higher alloy contents the critical speed of cooling is less, and the irons are martensitic as cast. In these irons tempering may be used to produce material which has hardnesses of over 300 Brinell, but is still machinable. If higher hardnesses are required, the parts may be machined after tempering, and subsequently re-hardened to higher levels by martensitic quenching. In all cases a stress-relief treatment at 250°C. is recommended.

This paper presents the first results obtained in a study of spheroidal-graphite cast irons having low critical quenching speeds. The six magnesium-treated irons used in the experiments reported contained nickel varying from 3 to 6·5 per cent., together with varying silicon and manganese. Two also contained 0·7 per cent. of molybdenum.

The full range of properties obtainable in such irons after various heat-treatments is recorded, and the effect of cooling rate on hardness is shown. Most of the test bars were unmachinable in the as-cast condition, but after tempering they could be machined, and the requisite strength and hardness could subsequently be developed by suitable heat-treatment. Values of the order of 400 Brinell, with a tensile strength of 76 tons per sq. in. were readily produced: in some cases figures as high as 500 Brinell and 83 tons per sq. in. are quoted.

Inter-Relation of Structure, Size and Properties in Spheroidal-Graphite Iron Castings

R. W. KRAFT and R. A. FLINN: 'Inter-Relation of Mechanical Properties, Casting Size and Microstructure of Ductile Cast Iron.'
Amer. Soc. Metals, Preprint 33, Oct., 1951: 25 pp.

This paper reports an investigation in which magnesium-treated cast irons were evaluated from three aspects:—

(1) variation in mechanical properties as a function of thickness, composition and heat-treatment;

(2) correlation of properties with steels having matrices similar to those of the cast irons;

(3) reproducibility of properties under commercial conditions.

Spheroidal-graphite cast irons having austenitic, ferritic, pearlitic, bainitic, and martensitic matrices were examined.

The results show that the properties of the irons follow the characteristics of steels having matrix structures of comparable types. The range of properties typical of the respective varieties is shown in the Table below.

It will be noted that, in the as-cast condition, the austenitic irons show the highest elongations, with moderate strength: the chromium-containing type exhibited lower elongation in the lighter sections. Stress-strain curves indicate a modulus of elasticity of 12,000,000 p.s.i. for the chromium-free type and 15,000,000 p.s.i. for the 1·5 per cent. chromium iron.

The ferritic irons had elongations similar to those of the austenitic irons, but showed generally higher yield and tensile values. The modulus of elasticity was also higher. In the as-cast state, pearlitic-structure irons showed wide variations in properties as a function of section size, but normalizing produced satisfactory consistency. High yield values and tensile strength were obtained, with moderate elongations. Irons having bainitic and martensitic matrices showed relatively low ductility, due to the high hardness. It is believed that the tensile data for these irons may be somewhat low, due to effects of small variations in alignment of specimen.

With regard to comparison of the spheroidal-graphite cast irons with steels of similar matrix structure, it is concluded that, given a correct combination of processing, composition and heat-treatment, excellent correlation is obtained. The cast irons of any given matrix structure show approximately 20 per cent. lower strength than the corresponding steel, due to the graphite present. The maximum

Effect of Variation of Matrix Structure on Mechanical Properties of Ductile Cast Iron

Matrix	Tensile Strength	Yield Strength	Elongation %	B.H.No.
Austenite Chromium-free	55,000-63,000 p.s.i. 24·5-28·1 t.s.i.	28,000-38,000 p.s.i. 12·5-17·0 t.s.i.	10·0-24·0	112-172
1 to 2% Chromium	31,000-76,000 p.s.i. 13·8-33·9 t.s.i.	27,000-43,000 p.s.i. 12·0-19·2 t.s.i.	2·0-19·5	147-185
Ferrite Heat-treated	57,000-79,000 p.s.i. 25·5-35·3 t.s.i.	43,000-60,000 p.s.i. 19·2-26·8 t.s.i.	9·0-25·0	144-195
Pearlite As-cast	75,000-136,000 p.s.i. 33·5-60·74 t.s.i.	55,000-90,000 p.s.i. 24·5-40·2 t.s.i.	0·0- 9·5	195-477
Heated-treated	75,000-136,000 p.s.i. 33·48-60·7 t.s.i.	55,000-90,000 p.s.i. 24·5-40·2 t.s.i.	1·5- 9·5	195-292
Bainite and Martensite	90,000-166,000 p.s.i. 40·2-74·0 t.s.i.	80,000-130,000 p.s.i. 35·7-58·1 t.s.i.	0·0- 5·0	150-448

hardness obtained in the magnesium-treated irons is lower than that for comparable steels, but the depth of hardening is equal or even greater. The tensile strength of the spheroidal-graphite irons is twice to three times that of normal cast iron of similar matrix structure, and elongation is five to twenty times greater. Such advantages are obtained in association with a degree of castability equal to that of normal cast iron.

The paper also includes a statistical report on six months' commercial production by means of the basic cupola, indicating the possibility of readily meeting, in large-scale production conditions, the specification of tensile strength 60,000 p.s.i. (27 tons per sq. in.), yield strength 45.000 p.s.i. (20 tons per sq. in.) and elongation 10 per cent.

A series of photomicrographs makes comparison of the influence of graphite form on the mechanical properties of cast irons. Specimens cut from tensile test-bar sections close to the position of fracture show the cracks which form between flakes of graphite, in contrast to the slip lines and transformation associated with elongated spheroids of graphite in magnesium-treated cast irons.

Heat-Treatment of Spheroidal-Graphite Cast Irons

J. E. REHDER: 'The Annealing and Heat-Treatment of Nodular and Other Cast Irons.' *Mémoires du Congrès International de Fonderie, Bruxelles*, Sept., 1951, pp. 313-24.

The author points out that in cast irons there is no single temperature at which austenite decomposes, but a temperature range in which austenite, ferrite and graphite exist in equilibrium in varying proportions, depending on the temperature and on the composition of the irons. He urges that many of the results used in the construction of the iron-carbon-silicon diagram most generally employed (see *Alloys of Iron and Silicon*, published by McGraw Hill Book Co., N.Y., 1933) are of doubtful validity, due, in part, to the rapid rates of cooling of the test pieces from which the data have been derived. In the investigations reported in this paper cooling rates employed were of the order of only 4°C. per hour.

The findings are summarized from the point of view of the influence of the various elements which may be present in cast irons:—carbon, silicon, manganese, phosphorus, nickel, and copper, on the location of the critical temperature range: the influence of these and other elements on behaviour during annealing is also considered.

The final section of the paper covers investigation of the quenching and tempering treatments which may be applied to spheroidal-graphite cast irons, and some of the properties which are obtainable by such treatments. Typical values for the mechanical properties of the irons in various conditions are shown in the table below.

The author states that work currently in progress indicates that by quenching and tempering of suitable irons it may be possible to achieve appreciably higher elongation at given yield strength or hardness. Structures obtained by the quench-and-temper treatment are associated with more uniform properties than as-cast or normalized structures.

Spheroidal-Graphite Cast Iron: Current Stage of Development

A. P. GAGNEBIN: 'Ductile Iron. Its Significance to the Foundry Industry.'* *Mémoires du Congrès International de Fonderie, Bruxelles*, Sept., 1951, pp.173-89.

The paper 'takes stock' of the present position of spheroidal-graphite cast iron, with respect to developments in methods of manufacture, properties regularly producible in the various grades of magnesium-treated iron, and the applications of the new materials.

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Oil-Quenched and Tempered at	Ultimate Tensile Strength	Yield Strength	Elongation %	Brinell Hardness	Charpy Impact, ft.-lb.	
					Unnotched	V-Notched
732	69,650 p.s.i. 31·0 t.s.i.	47,700 p.s.i. 21·3 t.s.i.	18·0	153	67	9·3
704	71,200 p.s.i. 31·8 t.s.i.	52,750 p.s.i. 23·5 t.s.i.	17·0	156	67	9·3
677	73,650 p.s.i. 32·9 t.s.i.	53,350 p.s.i. 23·8 t.s.i.	17·0	162	60	8·8
621	85,250 p.s.i. 38·0 t.s.i.	67,250 p.s.i. 30·0 t.s.i.	14·5	186	63	7·5
566	113,600 p.s.i. 50·7 t.s.i.	95,250 p.s.i. 42·5 t.s.i.	5·5	241	37	4·6
538	142,750 p.s.i. 63·5 t.s.i.	119,800 p.s.i. 53·5 t.s.i.	4·0	290	32	4·4
Normalized (Air-cooled)	127,500 p.s.i. 56·9 t.s.i.	80,300 p.s.i. 35·8 t.s.i.	6·0	253	35	12·8
Full annealed	66,000 p.s.i. 29·5 t.s.i.	47,350 p.s.i. 21·1 t.s.i	24·0	143	117	12·8

Statistics relating to the U.S.A. show that in 1949 (the first year of commercial production) 3,500 tons of iron were treated by the new process. In 1950 the figure rose to 15-20,000 tons, and for 1951 it is expected to exceed 50,000 tons. Castings in commercial production range from an ounce up to 50 tons in weight, and from $\frac{1}{10}$ in. to 48 in. in section.

The relationship of strength, hardness and elongation in spheroidal-graphite cast irons is illustrated by a graph based on results of tests on about 1,000 individual bars. The possibility of assessing strength and elongation on the basis of hardness is indicated.

Among the applications for which the new irons are finding increasing favour are pressure castings. Typical examples of such uses are quoted, and it is recorded that approval has recently been given by the Underwriters Laboratories, Inc., for pipe fittings to be made in these irons for use at pressures up to 2,000 p.s.i.

The author also reports highly satisfactory results of wear tests on spheroidal-graphite irons, under both laboratory and service conditions, and indicates some uses resulting from their wear-resisting properties. Applications described in the paper include gears, bearings, items of blast-furnace plant, grates, and annealing boxes. In connexion with the general value of the new irons to the engineering industries, mention is made of their high yield strength, weldability, and machinability, examples of which are quoted.

Future production will, it is considered, be much advanced by the use of the basic cupola, which gives a low-sulphur iron from charges containing no expensive or scarce materials. Extended use of the new irons is foreseen in many fields, some of which are not at present open to foundry products.

Engineering Applications of Nickel-Alloy and Spheroidal-Graphite Cast Irons

J. V. BAIRIOT and J. BERTHELIER: 'Nickel Cast Irons and Spheroidal-Graphite Cast Irons for Engineering.'* *Mémoires du Congrès International de Fonderie, Bruxelles*, Sept., 1951, pp. 249-62.

Developments in cast iron over the past 15 years are reviewed in this paper, with particular reference to improvements which have been effected in their mechanical properties. In this connexion the value of nickel-alloy cast irons is emphasized. The various grades of cast iron now available are discussed in relation to the requirements of the engineer, and the applications of the respective types, including the spheroidal-graphite irons, are reviewed, in sections relating to power stations, internal combustion engines, marine engineering, machine tools, and the chemical-engineering industries. The properties and applications of the engineering cast irons containing small, medium, and high percentages of nickel are included.

Spheroidal-Graphite Cast Iron as an Aid in the Conservation Programme

'Ductile Iron Saves Strategic Materials for Defense Program.' *Inco*, 1951, vol. 24, No. 4, pp. 12-13.

The article points out that spheroidal-graphite cast iron is of considerable interest in connexion with the re-armament programme, since it contains only small percentages of strategic materials, and offers production economies, due to reduced machining loss and better machinability, when used to replace other materials, such as steel forgings.

Complicated parts can be cast close to size (thus minimizing machining time), and special casting methods, such as the investment-casting method or the Croning process, can be used for production of specially intricate shapes. Examples of applications in which spheroidal-graphite cast iron can successfully replace steel forgings include generator shafts, gear racks, and crankshafts. For certain types of bearing the cast iron may be used in place of bronze.

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CONSTRUCTIONAL STEELS

Stress-Induced Transformation of Austenite in Nickel Steel

B. L. AVERBACH, S. G. LORRIS and M. COHEN: 'Stress-Induced Transformation of Retained Austenite in Hardened Steel.' *Amer. Soc. Metals, Preprint* 28, Oct., 1951; 11 pp.

Retained austenite sometimes present in quenched steels is not always decomposed at the relatively low tempering temperatures employed: for example, a recent study on a $3\frac{1}{2}$ per cent. nickel steel showed that tempering at temperatures up to 400°F. (205°C.) does not result in any appreciable conversion (*Amer. Soc. Metals, Preprint* 21, 1951). It was found, however, that the 6 per cent. of retained austenite present in the steel after tempering completely disappeared at the fracture of notched slow-bend specimens, even though the fractures were quite brittle.

In the present paper a report is made of measurements of the retained-austenite content of both slow-bend and V-notch Charpy bars of a 2340 nickel steel, as a function of distance from the fracture. X-ray examination was supplemented by a study of the stress-induced transformation of austenite, using tapered tensile bars in which fairly precise measurements could be made of the stress and strain conditions necessary to initiate and complete the transformation in the fully hardened steel.

After the bend and impact tests complete transformation of the retained austenite was observed at the fracture position, and some transformation was detected in all sections in which plastic strain had occurred. The retained austenite was completely converted before necking was observed. The stress-induced transformation proceeded more readily in untempered than in tempered steels: after tempering at 400°F. (205°C.) considerably higher plastic strains were required to produce transformation, an effect which is attributed to relaxation of strain embryos in the austenite during tempering.

Titanium, Niobium and Tantalum in Steels: Literature Review

See abstract on p. 268.

Hardenability Tests on Nickel and Other Alloy Steels

A. R. TROIANO and L. J. KLINGLER: 'Limitations of the End-Quench Hardenability Test.' *Amer. Soc. Metals, Preprint* 30, Oct., 1951; 11 pp.

The senior author recently reported an investigation of the transformation characteristics of three steels of comparable hardenability: S.A.E. 2340 (3½ per cent. nickel steel), 5140 (1 per cent. chromium steel) and 1340 (2 per cent. manganese steel): see *Trans. Amer. Soc. Metals*, 1949, vol. 41, pp. 1093-1112. The results then reported showed that for all three steels the amount of retained austenite increased to a maximum away from the quenched end of the hardenability bar, but that the nickel steel retained more austenite than the chromium steel at all corresponding positions, and that the manganese steel was intermediate. Metallographic examination of the same bars indicated that at all corresponding positions, beyond approximately ⅜-in., the austenite in the chromium steel had transformed to end products other than martensite to a much greater extent than had the austenite in the nickel steel, and that in this respect also the manganese steel was between the two. It was thus evident that although the steels possessed comparable hardenability curves, the relative proportions and the nature of the structures at corresponding positions differed appreciably. It was therefore concluded that the end-quench hardenability test may have serious limitations as a means of comparing various steels, even those of comparable hardenability, since variations in structure may exist which are not evident from hardness data.

This later paper reports tests on the same three steels, end-quenched in bars less than the standard 1-in. diameter. A sub-size bar of the nickel steel exhibited substantially greater hardenability than had been indicated by the standard end-quench test, whereas no change in hardenability was found for the two sizes of test piece in the case of the chromium steel. After controlled slack quenching the chromium steel exhibited considerable deterioration in properties, whereas, under the same conditions, loss of impact strength in the nickel steel was only slight.

Consideration of transformation characteristics and cooling curves and their relationship to quenched objects, as well as the notched-bar impact properties of the slack-quenched specimens, confirm the growing realization that the end-quench hardenability test does not always rate steels accurately with respect to their true hardenability or their ability to be hardened in various section-sizes. It would also appear that discrepancies in correlating end-quench curves with various quenched sections of the same or different steels may reflect substantial variations in properties and service performance.

Boron-containing and Other Low-Alloy Steels

'New Steel Compositions to Conserve Critical Alloying Elements.' *Materials and Methods*, 1951, vol. 34, Oct., pp. 135-137.

Tables showing compositions of steels developed in U.S.A. to conserve manganese, nickel, chromium and molybdenum.

Most of the low-nickel boron-containing types are as shown in an earlier list (see *Nickel Bulletin*, 1951, vol. 24, No. 6, p. 139), with provision for a few additional ranges of carbon content.

The new lists also contain details of plain and low-alloy types of Interim Alternate Steels ('T.S.' designation) and of steels for cold-heading and cold-forging wires.

Machining Qualities of Steels in Relation to Structure

'New Air Force Machinability Research Report Issued.' *Iron Age*, 1951, vol. 168, Oct. 11, pp. 110-14.

This article is based on 'United States Air Force Machinability Report, 1951', recently published by Curtiss-Wright Corporation. (An earlier report in this series was issued in 1950: for abstract of contents see *Nickel Bulletin*, 1951, vol. 24, No. 1, p. 6.)

The major section of Report No. 2 is devoted to presentation, in reference-handbook form, of machinability data on twelve commonly used steels:—1112 and 1020; 8620 and 8640; 3140, 4140 and 4340; 5140, 52100, and stainless steels of the 430, 410 and 347 types.

For each of these steels composition and properties are tabulated, the nature and application of the respective materials are indicated, general information is given on machining characteristics, and tool-life charts are provided. In many cases the report includes data on tool life obtained on the respective steels in various microstructural conditions resulting from the heat-treatments most generally used in commercial practice.

The extracts from the report given in the present article include a chart illustrating the way in which tool life varies as a function of the microstructure of the steel and the cutting speed. Effects of seven different microstructural conditions are demonstrated.

A further major feature of the research investigation was the correlation of cutting temperature with tool life. Results indicate that carbide tools generate no more heat than high-speed steel tools. Their superior performance is due to their greater hardness at high temperatures: typical cutting speed/temperature relationships are tabulated for 18-4-1 steel.

Nickel-containing Materials in the Engineering Field

'Designing with Modern Materials. A Comprehensive Survey of the Latest Developments in Engineering Materials.' *Machine Design*, 1951, vol. 23, Oct., pp. 297-374.

The simultaneous requirement for high production and for economy in strategic materials makes selection a matter of increasing importance to engineers. The summary presented in this article is intended to facilitate choice, by bringing together information on properties typical of some of the metallic and non-metallic materials which may be considered for various components.

Individual sections of the review contain data on new and modified constructional alloy steels developed to conserve nickel, molybdenum and other critical elements: heat - and corrosion - resistant steels;

electrical steels, and centrifugally-cast steels. Properties typical of ductile (magnesium-treated) cast iron are also tabulated, and the advantages of this new material in the engineering field are briefly noted.

In the non-ferrous section attention is directed to the most-recently-developed alloys of aluminium and magnesium base; to the mechanical properties of phosphor bronzes, tellurium-copper, beryllium-copper and other copper-base alloys, and to recent developments in titanium and its alloys, molybdenum, and tungsten and tungsten alloys.

In the review of heat- and corrosion-resistant alloys particular reference is made to Tantung, the cobalt-base Haynes Stellite alloys, Illium alloys and cemented-carbide-base materials. A large proportion of the materials considered in this group contain high percentages of nickel.

Recent developments in powder metals are also surveyed, and the final section of the review contains information on non-metallic materials of various types (ceramics and refractories, plastics, rubbers, insulating materials and lubricants).

Surface Hardening of Steel

G. T. COLEGATE: 'The Surface Hardening of Steel. Part IX. Nitriding and Cyaniding Processes.' *Metal Treatment and Drop Forging*, 1951, vol. 18, Oct., pp. 469-75.

In this instalment of the series the author compares the advantages and disadvantages of the nitriding and the carburizing processes. The points discussed are shown below:—

Advantages of Nitriding

Simplicity and ease of control.

Cleanliness of the work after nitriding.

Cheapness in operation (small amount of ammonia used; no packing compound; little labour required for supervision; low temperature of working, resulting in lower fuel costs and maintenance).

No after-treatment quenching required, thus minimizing risk of distortion, and reducing floor space and working costs.

Lessening of susceptibility to cracking.

Relatively small amount of finishing required, after nitriding, to make the part ready for use.

Disadvantages of Nitriding

Long period of treatment, by comparision with other case-hardening processes.

Necessity for use of steels of special composition.

With regard to the *properties* obtainable in the case by nitriding, the author draws attention to the following characteristics:—

Very high hardness (values of the order of 900-1,000 Brinell can be obtained in suitable steels).

Good wear-resistance.

Retention of hardness at elevated temperatures.

Improved fatigue-resistance.

Enhanced resistance to corrosion (by certain media only) and increased resistance to corrosion-fatigue.

The various properties are illustrated by reference to typical data.

If optimum service is to be obtained from nitrided parts, certain *limitations* must be considered:—

The corrosion-resisting qualities of the nitrided steel depend largely on the retention of the outer nitrided layer; if this is removed appreciable deterioration of corrosion-resistance will be found.

Unsuitability of nitrided steel for use in conditions involving the abrasive action of solid particles, e.g., sand-blasting nozzles.

Importance of adjusting treatment to produce a core of adequate strength, to back up the nitrided layer.

Applications of Nitrided Steels

Typical uses for which nitrided steels have proved suitable include valve stems working at elevated temperatures; cylinder liners; crankshafts; parts of aero engines, e.g., tappets, gudgeon pins, cams, camshafts, clutches, etc.; gauges and die blocks; pump parts; high-pressure steam valves.

Cyanide Case-Hardening and Similar Processes

Processes of this type, using both carbon and nitrogen as the hardening media, are intended to combine the advantages of both carburizing and nitriding. The author is of the opinion that such methods have not received the study which their potential value merits.

Cyanide hardening is suitable for treatment of small parts, especially where a relatively thin case is required, and on parts in which the load is likely to be light. Although principally used for low-carbon steels, the process may be applied on steels containing up to about 0·50 per cent. carbon. The case produced by cyaniding may contain 0·60 to 0·65 per cent. carbon with a nearly equal amount of nitrogen. Speed of cyaniding depends on operating at a relatively high temperature, and this method may be used for case-hardening some articles which could not economically be hardened by any other process.

A typical electrically-heated cyanide-bath furnace is illustrated in this article and some notes are given on handling of the work in hardening, and on stopping-off (by electrodeposited copper). Potassium cyanide was the main constituent of early types of cyanide case-hardening bath, but this has been replaced by sodium cyanide, and the advent of activated baths, containing carbonates or cyanogen compounds of the alkaline-earth metals (e.g., calcium and barium), has much increased the usefulness of the process. The influence of sodium-cyanide concentration, on case depth, is illustrated: it is generally considered that the bath should contain between 40 and 50 per cent.: means for maintaining this level are discussed. Chlorides are also sometimes added to cyanide baths, and since they tend to lessen pick-up of nitrogen they increase the carbon/nitrogen ratio in the case. In a few instances, a molten bath of pure cyanide may be employed for case-hardening, but this treatment is not used for many purposes.

Influence of Surface Condition of Steel on Spot-Test Results

See abstract on p. 251.

HEAT- AND CORROSION-RESISTING ALLOYS

Nimonic Alloys: Properties and Uses

HENRY WIGGIN AND CO., LTD.: 'The Nimonic Alloys.' *Publn.* 459*, 1951; 41 pp.

This publication presents general and engineering data on the extended range of Nimonic alloys now available to industry:—

Group 1 Creep-tested Wrought Alloys		Group 2 Wrought Alloys (Not creep-tested)		Group 3 Casting Alloys
Name	Specification	Name	Specification	Name
Nimonic 80	D.T.D. 725	Nimonic C		Nimonic CC
,, 80A	D.T.D. 736			
,, 90	D.T.D. 747	,, B		,, CB
		,, 75	D.T.D. 703	,, C75
		,, F	D.T.D. 714	,, CF
		,, D		

The essential nature of the alloys and their type compositions are summarized, and tabular and graphical data are presented on physical and mechanical properties, creep characteristics, hardness, fatigue-strength. The application of the data to design is demonstrated by a series of stress *v.* temperature and stress *v.* time diagrams relating to Nimonics 80, 80A and 90.

Information is also given on heat-treatment of the respective alloys, as specified in the D.T.D. schedules, or as recommended for alloys not yet covered by specification. Particulars of acceptance creep tests are summarized and explained.

A list of typical applications is added, classified according to uses in gas turbines, steam turbines, the automobile industry, heating and de-icing equipment, powder metallurgy, die casting, heat-treatment equipment, glass-manufacturing equipment, electronic apparatus, springs. A list is given of the forms in which the respective materials are available, and of the British patent numbers covering the series.

MOND NICKEL CO., LTD.: 'The Nimonic Series of Alloys. Their Application to Gas Turbine Design.' *Publn.* 440*a**, 1951; 28 pp.

The material contained is a revision and amplification of that first published in 1948, and revised in 1949 and 1950 in accordance with progress in the development of the Nimonic alloys.

It deals essentially with the properties of the alloys in relation to gas-turbine and other high-temperature uses, reviewing the following characteristics of various alloys of the group: creep- and fatigue-resistance, thermal expansion, corrosion-resistance, ease of fabrication. Individual uses in gas turbines are discussed in relation to selection of the Nimonic alloy best suited for the respective applications, e.g., Nimonic 75 for flame tubes, heat exchangers, nozzle guide vanes, and stator rings; Nimonics 80, 80A and 90 for blading; Nimonic C or CC for nozzle guide vanes.

Design data for use in construction with Nimonic alloys is given in a series of tables and curves showing physical and mechanical properties at various temperatures, and typical creep, fatigue, and torsion data.

* *We shall be pleased to supply a free copy of this publication.*

Sigma in Chromium-Cobalt-Nickel and Chromium-Nickel-Molybdenum Alloys

S. RIDEOUT, W. D. MANLY, E. L. KAMEN, B. S. LEMENT and P. A. BECK: 'Intermediate Phases in Ternary Alloy Systems of Transition Elements.' *Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1951, vol. 191, pp. 872-6; T.P. 3120E; *Jnl. of Metals*, Oct., 1951.

Following summary reference to earlier literature on the occurrence of σ in various systems, the authors report the results of an extensive research programme sponsored by the N.A.C.A. in the laboratories of the Dupont Company. The work covered study of several ternary systems containing solid solutions and also some new ternary phases. The present paper records investigation of the 1200°C. isothermal sections of the following phase diagrams: Cr-Co-Ni, Cr-Co-Fe, Cr-Co-Mo and Cr-Ni-Mo. The results indicate that the range of existence of the σ phase in these four systems, and also in one or two ternary systems studied by other investigators, can be fairly consistently described in terms of electron-valency concentrations. This conclusion supports the suggestion made by SULLY and HEAL (*Research*, 1948, vol. 1, p. 288) that the σ phase is an electron compound.

The authors give a full description of their experimental technique, and report their results in the form of diagrams showing isothermal sections at 1200°C. for the respective alloys. Typical X-ray diffraction patterns are also tabulated for some of the alloys.

The data recorded lead the authors to the following conclusions:—

'In the Cr-Co-Ni, and Cr-Co-Fe phase diagrams at 1200°C. the Cr-Co σ phase forms elongated fields

extending deeply into the ternary systems. The extension of the ternary solid solution fields suggests that in these systems nickel (or iron) is capable of partially replacing cobalt in forming the σ phase. At 800°C. the σ-solid-solution field extends all the way from the Cr-Co σ phase to the Cr-Fe σ phase across the Cr-Co-Fe ternary diagram, so that here Fe and Co are completely replacing each other.

'In the Cr-Co-Mo system at 1200°C. the Cr-Co σ phase forms an elongated field of ternary solid solutions, suggesting that molybdenum is capable of partially replacing chromium in forming the σ phase.

'In the Cr-Ni-Mo system, in which no binary σ phase is known to occur, at 1200°C. σ solid solutions form a ternary phase in which chromium and molybdenum may partially replace each other.

'The above results may be interpreted in terms of electron-vacancy concentrations. A condition for the occurrence of the σ phase appears to be the attainment of a range of electron-vacancy numbers per atom intermediate between that in the face-centred-cubic transition elements, nickel, cobalt, iron, and in the body-centred-cubic transition elements, chromium and molybdenum.

'In the Cr-Co-Mo system a new ternary phase *R* was found in a small concentration range between the σ and μ phases. In the Cr-Ni-Mo system another new ternary phase, *P*, was located between the σ and δ phases. The X-ray diffraction pattern of *R* is different from that of *P*, and both patterns appear to be different from those of all known phases in alloys of the transition elements.'

Electrolytic Etching for Detection of Sigma Phase

J. J. GILMAN: 'Electrolytic Etching: The Sigma Phase Steels.' *Amer. Soc. Metals, Preprint* 12, Oct., 1951; 31 pp.

The work described was undertaken primarily to develop new etching reagents which could be used for identification and study of the sigma phase in steels. A study was also made of discrepancies which had been observed in the behaviour of certain alkaline etching reagents which had been previously used.

Initially the intention was to seek a reagent similar to Murakami's solution, but one which would be stable against decomposition and more selective in its attack of the various constituents of high-chromium steels. For most of the experiments reported the two types of steel shown in the Table below were used.

Since the rôle of the potassium ferricyanide appeared to be simply that of an oxidizing agent, the author made tests with various etchants in which other oxidizing agents were used, e.g., picric acid, potassium permanganate and potassium dichromate. All of the alkaline solutions containing such additions were effective, but none proved to be highly selective. The investigation was therefore considerably extended, to cover a systematic study of a number of other reagents.

Following preliminary experiments which established that plain hydroxide solutions delineate the microstructures of the steels as effectively as alkaline etchants containing oxidizing agents, the behaviour of several common hydroxides was studied: ammonium, barium, lithium, potassium, sodium, strontium and tetramethyl ammonium hydroxides. Results obtained are illustrated by photomicrographs, and are tabulated and described. The mechanism of etching with hydroxide reagents is critically discussed.

On the assumption that in hydroxide solutions ferric hydroxide precipitates on the carbides and sigma phase, it was considered likely that other salt solutions in which the anion forms an insoluble ferric compound would form stain films on the constituents of the steels. Such solutions were therefore tested: ammonium, cadmium, chromium and lead acetates were used, also sodium oleate, potassium ferricyanide and potassium thiocyanate. The results of this series are also shown in tabular and photomicrographic form.

The results of the experiments lead to recommendation of the following procedure for identification of sigma:—

> Etch electrolytically in 10 per cent. potassium hydroxide just long enough to colour the sigma phase, but not the carbides, and follow by etching electrolytically in concentrated ammonium hydroxide, to colour the carbides but not the sigma phase.

Tests made on a series of typical heat- and corrosion-resisting steels susceptible to sigma formation proved this procedure to be satisfactorily discriminating.

Inter alia, it is shown that concentrated hydroxide solutions used electrolytically colour the sigma phase more rapidly than the carbides in stainless steels, and *vice versa* if the solutions are dilute. An explanation of this effect is proposed.

In the tests with acetate etchants, cadmium- and lead-acetate solutions were found to be of particular interest, since the former colours carbides more rapidly than sigma, and the latter reveals the microstructure in vivid colours, and the carbides with unusual clarity.

The author discusses the mechanism of the etching action of the solutions which stain the constituents of stainless steels. Observations on coloured films produced by such etchants support the interference theory of the origin of the colours.

It is shown that the 'characteristic cracks' in the sigma phase which have been noted by various investigators are associated with the etch film, and not with cracks in the underlying sigma phase.

	C %	Mn %	Si %	Ni %	Cr %	Mo %
Type 314	0·09	1·27	2·14	20·0	24·92	—
Cast Valve Steel	0·40	0·75	1·10	6·4	24·0	4·2

Fracture Characteristics of High-Temperature Alloys in Relation to Direction of Forging

W. F. BROWN, H. SCHWARZBART and M. H. JONES: 'Tensile-Fracturing Characteristics of Several High-Temperature Alloys as Influenced by Orientation in Respect of Forging Direction.' *Nat. Advisory Committee for Aeronautics, Research Memorandum R.M. E50L28*, Feb. 12, 1951; 32 pp.

Hot or cold deformation of metallic materials can produce anisotropy, or directionality, of the mechanical properties. Such anisotropy is of two main types: crystallographic anisotropy, due to preferred orientation of the metal crystals, and mechanical anisotropy, due to orientation and elongation of inclusions, cavities and precipitates, which occur during working and produce a fibrous structure. It has been shown that crystallographic anisotropy resulting from cold working may persist after annealing if the cold deformation has been severe, and stress-strain and fracture properties of such material will vary with direction of testing. The magnitude of the effects varies with the past working and thermal history of the material. Mechanical anisotropy, or fibering, results primarily from hot working, and, in some cases, is difficult to remove by any reasonable form of heat-treatment. Transverse ductility, e.g., of forgings, may be less than one-half the value of that obtained in the direction of forging.

Turbine components, such as blades, blade fastenings, and wheels, undergo plastic flow during service, and the life of such parts may be influenced by either one or both of the anisotropies described.

In view of the above considerations, a study was made of mechanical anisotropy in the following materials: S-816, Inconel X and 16-25-6 alloy, chosen as representative, respectively, of cobalt-nickel-chromium, and nickel- and iron-base high-temperature alloys. The influence of direction of test, in relation to forging direction, on the true stress-strain and fracture characteristics was studied, on forgings of 4-in. diameter, selected to approach the conditions obtaining in commercial fabrication. Tensile tests at room temperature were considered to be most suitable as a criterion: orientation angles from 0° to 90° (between the forging direction and the axis of the specimen) were investigated. Changes in properties observed were correlated with the microstructure of the forgings.

The results showed mechanical anisotropy in all the materials: it was pronounced in 16-25-6, somewhat less for S-816, and small for Inconel X. Ductilities of 16-25-6 specimens having orientations greater than 60° were less than one-half of the values obtained in the direction of forging. The anisotropy of this material was associated with planes of precipitate which were parallel to the direction of forging in the original bar: they constituted the fracture plane of specimens at orientations greater than 60°.

For all three materials the fracture stress and ductility decreased rapidly in the range of orientation from 40° to 60°, and from there remained constant to 90°.

The identity of true stress-strain curves for specimens of various orientations, and the fact that the specimens were circular in cross section at the fracture, indicated that the alloys were essentially crystallographically isotropic.

Influence of Surface Finish on Fatigue of High-Temperature Alloys

R. R. FERGUSON: 'Effect of Surface Finish on Fatigue Properties at Elevated Temperatures. I. Low-Carbon N-155 with Grain Size of A.S.T.M. 1.' *Nat. Advisory Committee for Aeronautics, Report RM. E51D17*, June 26, 1951; 18 pp.

Information obtained on various materials has indicated that smoothness of surface, state of stress in the surface, and the amount of cold-work in the surface are the primary factors affecting fatigue life of surfaces at room temperature. The investigation reported in this paper was undertaken to determine the influence of surface condition on fatigue properties at elevated temperatures.

The material, N-155, was tested in three conditions of surface finish, having, respectively, roughnesses of 4-5, 20-25, and 70-80 microinches r.m.s. The tests were made, in a high-temperature fatigue-testing machine which is described and illustrated, at temperatures of 80°, 1000°, 1350° and 1500°F. (26·8, 538°, 734° and 815°C.).

The results of the tests (reported in detail) show that at room temperature each type of finish was associated with a characteristic fatigue strength, but that at elevated temperatures this difference was not apparent.

At room temperature the rough finish was superior in strength to the polished material, and the polished material was, in turn, superior to the ground alloy. It is believed that this variation is due to a difference in the degree of surface stress present at the surfaces finished by the various methods: the ground surface appeared to be relatively stress-free, whereas the polished and rough surfaces probably contained compressive stresses.

At 1000°F. (538°C.) specimens with a polished finish were stronger than those with a ground finish, for periods up to 5,000,000 cycles of stress (approximately 14 hr. at temperature). For longer tests, the difference between the strength of the polished and ground specimens was not appreciable.

At 1350°F. (734°C.) no significant difference in strength was found between specimens with polished, rough, and ground finishes. At 1500°F. (815°C.) the ground and polished specimens had the same strength. It is believed that the beneficial compressive stresses present in the polished and rough specimens were relieved by annealing in test periods and at those test temperatures at which the strengths of the various specimen finishes were the same.

Ceramic Coating of High-Temperature Alloys for Aero Engines

W. G. HUBBELL: 'Ceramic-Coated Exhaust Systems. *Aircraft Production*, 1951, vol. 13. Nov., pp. 357-62.

The author reports tests carried out by the Ryan Aeronautical Company, San Diego, California, to determine the possibility of using ceramic coatings

to prolong the life of components of exhaust systems.

The conditions involved in exhaust systems are of extreme severity, including continual blasts of high-velocity gases, severe vibration, and sub-zero atmospheric conditions, combined with operation for extended periods at temperatures as high as 1800°F. (980°C.).

The paper records comparative tests made on exhaust headers of the following materials, subjected to service in Pan American Stratocruisers:—

19-9DL stainless steel, 0·043-in. gauge, with ceramic coatings on both interior and exterior.
19-9DL stainless steel, 0·043-in. gauge, with ceramic coatings on interior only.
19-9DL stainless steel, 0·043-in. gauge, uncoated (three control headers).
17-14 CuMo steel, 0·043-in. gauge, uncoated.
310 modified stainless steel, 0·043-in. gauge, uncoated.
310 with niobium added, 0·043-in. gauge, uncoated.
Inconel X, 0·043-in. gauge, uncoated.
N-155, 0·043-in. gauge, uncoated.
Hastelloy C, 0·043-in. gauge, uncoated.

The test headers were removed after intervals of approximately 650, 1000 and between 1234 and 1623 hours, and were subjected to tests comprising metallographic examination, spectrographic analysis, microhardness determinations, and dial-gauge micrometer observations.

The condition of each of the materials after various periods of service is recorded, and the descriptions are illustrated by photomicrographs showing the surface appearance of typical specimens. The thermal-shock resistance of the ceramic coating applied to the 19-9 DL headers was also determined, by an extremely severe test, full details of which are given.

The results show that, under all the conditions of test imposed, the presence of the ceramic coatings on the headers successfully prevented them from deterioration from oxidation, carbon-absorption and corrosion attack. By comparison, all the other materials had suffered appreciable deterioration, varying in intensity from one type to another.

Additional tests are being made by Ryan, but it is considered to have been already definitely established that ceramic coatings are beneficial in extending the life of the heat- and corrosion-resistant alloys in conditions in which oxidation and corrosion are major problems. The ceramic coatings are extremely thin (of the order of 0·001-0·002 in.): the weight-increase involved is negligible, amounting to only about 2 per cent. on 0·065-in. gauge material. Heavy coatings would tend to spall during cooling from the firing temperatures.

Parts treated with the thin coatings will withstand a considerable amount of rough handling. For example, it has been found that if re-alignment of parts is necessary after application of the coatings the parts may safely be placed in jigs, and that rubber mallets can be used, and alignment jacks and alignment torch operations may be applied, without occurrence of chipping, crazing or other damage. Tests have shown that the ceramic-coated parts are not affected by thermal shock due to alternations of temperature over the range −75°F. to 1700°F. (24° to 925°C.).

It is stated that some 600 sets of ceramic-coated exhaust assemblies have been ordered for Pratt and Whitney engines, for Convair transports, and that the Boeing Airplane Company has ordered ceramic-coated assemblies for all its B-50 bombers and C-97 Stratofreighters now under production for the U.S. Air Force. In the gas-turbine field, the General Electric Company has given experimental orders for ceramic coating of the transition liners and inner combustion chambers for the J-47 engine. Experimental work is also being conducted with the Douglas Aircraft Company and United Air Lines, on ceramic coating of DC-6 transport exhaust assemblies, by means of service tests on scheduled runs.

U.S. Standard Specifications for Nickel and Nickel Alloys

See abstract on p. 255.

Welding of Nickel-Chromium-Iron Alloy Castings

R. H. ENGLISH: 'High-Temperature Welded Joints.' *Welding Jnl.*, 1951, vol. 30, Oct., pp. 907-10.

The author deals with welding technique for use on three main types of casting: 25-12 chromium-nickel (A.C.I. HH type); 25-20 chromium-nickel (A.C.I. HK type), and 15-35 chromium-nickel (A.C.I. HT type). The respective spheres of application of these grades are briefly outlined. Reference is also made to a new weldable casting alloy of unspecified composition, recently developed by National Alloy Steel Division of Blaw-Knox Company; this is specially designed for service in the range 2000°-2150°F. (1095°-1175°C.).

The above alloys are usually welded by the shielded-metal-arc process, with d.-c. reversed polarity. Lime- and titania-type coatings are used. When employing the former, chromium loss in welding is reduced, but the slag is somewhat more difficult to remove. Quarter-inch diameter rods are extensively used, and it is seldom necessary to employ rods smaller than $\frac{5}{32}$-in. in diameter. Inert - gas - shielded metal-arc welding of these alloys has proved successful, and the high-temperature properties of welds made by this process are equivalent to those produced by the shielded-metal-arc process. Inert-gas-shielded metal-arc welding with tungsten electrodes has been used to a limited extent and the submerged-arc process, with automatic heads, has also been successfully applied, as has oxy-acetylene welding.

Tests have been developed, by the author's Company, for determination of the thermal fatigue of welded joints of high-temperature materials, and for the study of the behaviour of welds over long periods of time at service temperatures. Particulars of the two forms of test are given in the paper.

Particular attention is directed to the importance of welding in radiant-tube assembly, and to retorts and muffles, as further examples of castings which are joined by welding. In both cases the production of gas-tight joints is essential: this is ensured by a drastic pressure test applied to the welded parts before installation. Some typical units are illustrated.

Palladium-containing Brazing Alloys

MOND NICKEL CO., LTD.: 'Palladium-containing Brazing Alloys for High-Temperature Materials.' *Publn.* 555, Sept., 1951; 1 p.

This brief publication gives short-time shear test results and creep data on joints in Nimonic 80 made with palladium-containing alloys developed in the Company's laboratories. Notes on brazing technique suitable for use with these alloys are added.

Resistance of Nickel-Chromium Steels to Bismuth Alloys

J. L. EVERHART and E. L. VAN NUIS: 'High Chromium Steels Resist Attack by Liquid Bismuth Alloys.' *Materials and Methods*, 1951, vol. 34, Oct., pp. 112-14.

Liquid metals have certain definite advantages as heat-transfer media. They have high thermal conductivities; their heat-transfer coefficients are among the highest known; they do not decompose; most of the metals under consideration have high boiling points, thus permitting operation of equipment at relatively low pressures; their use allows of electromagnetic pumping, thus simplifying the pumping problem by eliminating moving parts and packing. Liquid metals may, however, be severely corrosive, necessitating careful selection of constructional materials for containers, etc.

Among the metals under consideration as heat-transfer media are mercury, sodium-potassium alloys, and bismuth alloys. The authors briefly indicate the limitations of the first two types, and discuss in greater detail the properties of bismuth alloys, as affecting their employment in this type of service. It is pointed out that they have many advantages for this purpose, but that their practical usefulness depends, to a large extent, on the selection of suitable constructional materials to handle them.

Earlier investigations have shown that the rate of attack of bismuth-lead alloys on nickel and high-nickel alloys, copper and copper-base alloys, and cobalt alloys is too high for these materials to be used. Among the steels, the high-chromium types are more resistant than the nickel-chromium grades.

Conditions	Suitability for Service *		
	Good	Limited	Poor
Bismuth-Lead at 900°F. (482°C.)	304 309 310 446 4% Chromium-titanium Vanadium		Titanium
Bismuth-Lead at 1200°F. (648°C.)	309 Ni-Cr Steel 310 Ni-Cr Steel 446 Cr Steel	304 317	4% Chromium-titanium
Bismuth-Lead-Tin at 1200°F. (648°C.)	446 4% Chromium-titanium	304	309 310 317 420 Titanium Vanadium
Bismuth-Indium-Lead at 1200°F. (648°C.)	304 Vanadium	446	309 310 Titanium 4% Chromium-titanium

* *Basis of Rating* — *Mg/Sq.cm/Month*

Good	Less than 1·6
Limited	More than 1·6 less than 17
Poor	More than 17

Type 309 rated on basis of service as container for liquid metals.

Little information has previously been available on the rates of attack of other bismuth alloys, but this article reports tests on stainless steels (Types 304, 317, 310, 420 and 446), titanium, 4 per cent. Cr chromium-titanium steel, and vanadium, exposed to the following types of alloy: bismuth-lead, bismuth-lead-tin and bismuth-indium-lead.

On the basis of the results the general recommendations in the Table on p. 267 are made, but they are given with the warning that in selection of materials of construction due consideration must be given, not only to the composition of the alloy, but also to conditions of temperature, rate of circulation, and purity of the alloy.

The work on which this paper is based was carried out in the Research Department of the American Smelting and Refining Company, under contract for the U.S. Atomic Energy Commission.

Prevention of Zinc Embrittlement of Nickel-Chromium Stainless Steels

'Drop-Hammer Operation.' *Aircraft Production*, 1951, vol. 13, Oct., p. 327.

This note describes procedure standardized in the drop-hammer department of Ryan Aeronautical Company, San Diego, California. Between 14 and 18 separate operations are carried out in this department and many parts go through four distinct forming stages during manufacture. Metal arrives in the shape of rough-out blanks. It is identified, oiled, and formed in the first-stage dies of the drop hammer, giving the material its first contour. In the case of corrosion-resisting austenitic steels this forming begins to work-harden the material.

After first forming, the parts are de-greased in an alkaline bath, washed with water, and freed from adhering zinc by treatment in a 20 per cent. solution of nitric acid. (The importance of this de-zincing treatment in the case of austenitic steels was emphasized in a note on the experience of Airspeed, Ltd., in treatment of heat-resisting steel: *ibid.*, July, p. 201; *Nickel Bulletin*, 1951, vol. 24, No. 8, p. 181.)

After the pickling operation the parts are heated in a gas-fired electrically-controlled normalizing oven, at 1800°F. (980°C.), for approximately 15 minutes, to remove stresses induced by forming. They are then oiled, and stamped in a second drop-hammer die, to carry the forming a stage further, after which they are removed from the drop hammer, trimmed to remove surplus metal, again de-greased and de-zinced, and normalized to remove stress. After normalizing they are immersed in a pickling solution of caustic salt, to remove scale, and are washed with water.

A third and final forming stage follows, to provide accurately square corners for the welding process, and good contact between all surfaces which are butted together. The parts are then squared with air-driven planishing hammers, which remove any wrinkles and give 90° angles on all corners. A final adjustment of dimensions is given by the drop hammer, and the parts are then de-greased and de-zinced, and delivered to the welding department.

Stainless Steel in Mobile Army Shower-Baths

'Army Develops Stainless Steel Mobile Shower Bath for Korea.' *Materials and Methods*, 1951, vol. 34, Oct., pp. 190, 192, 194.

A mobile shower-bath unit now serving front-line troops in Korea is so light and compact that it can be towed by a jeep. In view of the fact that the water which must be used is likely to be contaminated with bacteria, provision is made in the shower-bath set-up for sterilization. The working of the unit is described in this note.

Materials of construction were of considerable importance in construction; notes are given on the reasons which dictated the choice of the types used for the respective parts. Trailer, frame and cover, many of the structural parts, and the shower pipes, are of aluminium alloy. Individual axle units with articulated parallel linkages and individual torsion springs are steel, as is the towing lunette, or eye. The water-blender and showerheads are of brass. Due to the current need for conservation of stainless steel, the use of this material for the boiler and heat exchangers was not envisaged in the original plans, but the following considerations led to authorization of stainless for these parts:— a very large heating and heat-transfer capacity had to be packed into a very small unit. Parts had, of necessity, to be so small that mechanical cleaning is impracticable. Operation with all types of water—hard, soft, muddy or swampy—presents difficult problems of cleaning and de-scaling. By using stainless steel these problems are solved. The tubes are flushed out with 20 per cent. nitric acid, a treatment which would corrode most other materials. The service life of the stainless-steel boiler and heat exchangers is estimated at 1,000 operating hours, whereas it is believed that the next best material for the purpose would have given only 250 operating hours.

Nickel-containing Materials in the Engineering Field

See abstract on p. 261.

Titanium, Niobium and Tantalum in Steels: Literature Review

A. KOHN: 'Comparison of the Effects of Additions of Titanium, Niobium and Tantalum on the Properties of Steels.' *Rev. de Métallurgie*, 1951, vol. 48, Sept., pp. 687-711.

The survey reported has been made to provide an up-to-date statement of the effects of niobium in various types of steel, with particular reference to the comparative influence of niobium, titanium and tantalum.

The first section comprises a discussion of the binary diagrams of the three elements, with iron and with carbon; the second section contains a discussion of the influence of the addition metals on the properties of iron and of iron-carbon alloys. Consideration is given to the nature of their action, the occurrence of structural hardening in materials containing the elements, and their effect on hardenability, intercrystalline corrosion, ageing, temper-brittleness, creep-resistance, susceptibility to nitriding, and hot-workability.

This is followed by a review of the influence of additions of these metals on the properties of individual types of steel (constructional, straight high-chromium, chromium-manganese and austenitic nickel-chromium steels).

The review is supported by a *bibliography* of 60 references.

Influence of Nickel on Stability of Structure in Austenitic Nickel-Chromium Steels

P. BASTIEN, J. DEDIEU and A. PORTEVIN: 'Effect of Strain Hardening and Tempering on 18-8 Stainless Steels.' *Metal Treatment and Drop Forging*, 1951, vol. 18, Oct., pp. 465-72. Translation of paper from *Métaux et Corrosion*, 1950, vol. 26, Dec., pp. 308-11, abstracted in *Nickel Bulletin*, 1951, vol. 24, No. 4, p. 88.

Report of experiments on two 18-8 type steels, containing, respectively, carbon 0·035 with chromium 18·3 and nickel 10, per cent., and carbon 0·040 with chromium 17·8 and nickel 9, per cent.

Passivation Anomalies in Austenitic Nickel-Chromium Steels

R. KNOX: 'Passivity of Type 304.' *Metal Progress*, 1951, vol. 60, Sept., pp. 77-8.

The writer records details of some anomalous effects observed in tests on three specimens of Type 304 18-8 chromium-nickel steel, in a 15 per cent. aqueous solution of sulphuric acid containing about 1·25 per cent. of sodium chloride. The tests were made at 140°–180°F. (60°–88°C.). The suggestion is tentatively advanced that the presence of 0·18 and 0·17 per cent. of molybdenum in two of the samples accounts for the difference between the behaviour of these two steels and that of a 304 steel free from molybdenum. Certain relevant observations on the behaviour of Type 316 (18-12 chromium-nickel containing 2½ per cent. molybdenum) are also recorded.

Nitric-Acid Corrosion Tests on Extra-Low-Carbon Stainless Steel

H. F. EBLING and M. A. SCHEIL: 'Corrosion Data of Welded Low-Carbon Stainless Steel.' *Welding Jnl.*, 1951, vol. 30, Oct., Suppl., pp. 511-18.

The A.O. Smith Corporation, which has for many years specialized in production of stainless-lined vessels for chemical-engineering applications, uses the standard (Huey) nitric-acid test as the inspection method. Specimens prepared for quality control by this procedure represent the equipment in the finally fabricated condition, which includes all the thermal treatments to which the material is subjected. This Company has been a pioneer in the use of extra-low-carbon (0·03 per cent. max.) Type 316, and it is recorded that there have been no tests in which such material has been sensitized by the welding operation. The steel shows somewhat lessened resistance to corrosion after low-temperature stress-relief treatment, in the range 900°-1200°F. (480°-650°C.): this is revealed by the nitric-acid test, but not under the acidified copper-sulphate test, a difference which is explained as due to the fact that the latter reveals only sensitization due to precipitated carbides, whereas the nitric-acid test reveals sensitization resulting from both sigma-phase formation and carbide precipitation.

This paper reports a series of laboratory experiments in which comparison was made, on the basis of the nitric-acid test, of unstabilized extra-low-carbon Type 304, and three stabilized steels, A.I.S.I. Types 347, 347+Ta, and 321. In view of the fact that the main interest of the tests was in material for lining of vessels, the tests were confined to sheet less than 0·125 in. thick. Parent material and arc-welded specimens were tested, and heat-treatments simulating fabricating conditions were applied according to A.S.M.E. Code requirements for unfired pressure vessels.

Full details of the respective series of tests are given and a tabular summary is made of rating for the following materials and welds:—

Parent Material	*Electrode Material*
304 (Extra-low C)	308 (Extra-low C)
304 (Extra-low C)	347
347	347
347 + Ta	347
347 + Ta	308 (Extra-low C)
347 + Ta	347 + Ta
321	347

The results show that in all conditions except after long-time sensitization treatment at 900° and 1000°F. (480° and 540°C.) the extra-low-carbon Type 304 shows the best nitric-acid corrosion-resistance. Welding this type of material with extra-low-carbon Type 308 or Type 347 electrodes does not sensitize any portion of the heat-affected zone.

The extra-low-carbon Type 308 weld deposit proved inferior to the 347 deposit in resistance to corrosion, but it has a good possibility of stabilizing itself at temperatures of 1000° to 1200°F. (540° to 650°C.) and thus becoming considerably better than Type 347 deposits for high-temperature service. It is expected that a stabilizing heat-treatment prior to low-temperature sensitizing may be very effective in reducing susceptibility to corrosion in the nitric-acid test. The authors have in progress tests to determine the effectiveness of a number of stabilizing heat-treatments prior to long exposure at 900° to 1000°F.

The tests rate Type 304 extra-low-carbon, welded with Type 347 electrodes, as best for all the fabrication types of heat-treatment. Type 347+Ta with a Type 347 weld is rated second, a position which is believed to be due rather to the high ratio of stabilizing elements to carbon than to the presence of tantalum. Niobium-stabilized steels having a lower ratio of stabilizers to carbon showed knifeline attack and lower corrosion-resistance. The titanium-stabilized steels were rated lowest in the nitric-acid test.

The authors urge that 'if the presence of niobium, tantalum or titanium does not enhance the corrosion-resistance of the 18-Cr/8-Ni alloys other than to minimize possible sensitization, then there is no reason that the Type 304 extra-low-carbon alloy is not an effective substitute for the stabilized grades of alloys for service applications under 800°F. (425°C.)'.

Determination of Nickel in High-Alloy Steels

See abstract on p. 250.

Complex Nickel-Molybdenum-Chromium Alloys for Resistance to Hydrochloric Acid

H. ENDO and S. ISHIHARA: 'Effects of Various Elements on the Hydrochloric Acid Resistivity of Nickel-Molybdenum-Chromium Alloys.' *Science Repts., Research Inst., Tôhoku Univ., Ser. A.*, 1950, vol. 2, No. 4, Aug., pp. 632-6.

Alloys of the Hastelloy and similar types, although satisfactorily resistant to attack by hydrochloric acid of high concentration, corrode to an undesirable extent in more dilute solutions of the acid, especially in the presence of oxidizing agents.

This paper records tests made to determine the possibility of improving resistance to dilute acids by means of additions of ferro-alloys. Exposure of the specimens was made in 10, 20 and 30 per cent. hydrochloric acid at room temperature, and in 10 and 20 per cent. acid at boiling point. In the former series the duration of test was 15 days; in the latter 5 hours.

The compositions of the alloys tested were adjusted to demonstrate the influence of ferro-tantalum, ferro-vanadium, ferro-zirconium, ferro-titanium, copper+beryllium, cobalt, and tungsten+copper, on the corrosion-resistance of nickel-molybdenum-chromium-base alloys. The range of materials included commercial corrosion-resisting alloys such as Illium, Hastelloys A and C, Duriron, Nemic, and Stellite, as well as experimental alloys.

A tabular summary of the loss-in-weight determinations made on the individual samples after test led to the following conclusions:—

Ferro-vanadium additions were very effective.

Ferro-tantalum, ferro-zirconium, copper+beryllium, tungsten, cobalt, and copper had only slight effect: in some cases they were beneficial, but ferro-tantalum had, in some other cases, an unfavourable influence.

Ferro-titanium was deleterious in all cases.

In 10 per cent. hydrochloric acid at room temperature the nickel-base alloy containing molybdenum 30, chromium 15, ferro-vanadium 0·5, per cent. was outstandingly the most resistant alloy tested.

Testing of Metallic Materials for Resistance to Phosphoric Acid

H. F. EBLING and M. A. SCHEIL: 'A Standard Laboratory Corrosion Test for Metals in Phosphoric-Acid Service.' *Trans. Amer. Soc. Mechanical Engineers*, 1951, vol. 73, Oct., pp. 975-87; disc., p. 987.

The paper reports work done by the A. O. Smith Corporation in developing a standard test for determination of resistance to phosphoric acid, with particular reference to the use of stainless steel in construction of equipment handling the acid.

Methods by which phosphoric acid is produced are briefly considered, and existing data on resistance to attack by it are reviewed. It is noted that much of the information which has been published is not of full use, due to variations in factors such as purity of acid, degree of aeration, and velocity, all of which vitally affect the extent of the corrosion attack.

The following procedure has been standardized by A. O. Smith for testing material for lining of vessels to be used in a gas-polymerization process in which phosphoric acid is the catalyst, and for other applications in which stainless steel is in contact with the acid:—

'*Preparation of Sample*

The size of the specimen generally used for this test is approximately 2-in. long, 1-in. wide, and the full thickness of the supplied sheet. The identification of the sample is stamped at one end of the specimen. Any necessary heat-treatment of the sample should be carried out at this point. The specimen is then ground and polished to a 180 Aloxite finish. Care is taken so that the specimen does not have cold-worked edges caused by shearing, or overheated areas caused by prolonged or excessive grinding. New Aloxite paper or cloth should be used for each alloy, in order to prevent possible surface contamination. Micrometer measurements are taken of each dimension and the surface area is computed. The specimen then is weighed to the nearest milligram.

'*Apparatus and Supplies*

The apparatus consists of the standard corrosion equipment in which a wide mouth 1 litre Pyrex Erlenmeyer flask is used. The condenser for the apparatus is the cold-finger type. The specimens are introduced and taken out of the acid by means of a small glass basket. A standard electric hot plate is used to furnish sufficient heat, so that the acid gently boils throughout the testing period. Baker's C.P. 85 per cent. orthophosphoric acid is used. This acid has a specific gravity of 1·71 and boils at 160°C. (320°F.). No substitution should be made for this acid. The amount of acid used should be in proportion to the surface area of the specimen: a minimum of 60 ml. of acid per sq. in. of surface is used.

'*Test Procedure*

The specimen is placed in a glass basket and is introduced into the cold acid, the condenser set into position, the assembly placed on the hot plate and brought to boil. The time is taken when the acid begins to boil. The time for one period or boil is 24 hours. At the end of the period the specimen is removed from the hot acid and washed in warm water. The specimen is dried by an air blast and again weighed to the nearest milligram. Only one specimen is run in each flask and fresh acid is used for each test period or boil. On most materials three 24-hour periods are generally sufficient to establish a uniform corrosion rate.

'*Calculation of Corrosion Rate*

The penetration in inches per year is calculated for each period from the following formula:—

$$\text{Corrosion rate in IPY} = \frac{W}{1{\cdot}9 \times D \times A \times T}$$

where—

IPY = inches penetration per year.

W = loss in weight in milligrams expressed as a whole number.

D = density of material.

A = area, sq. in.

T = time, hr.

For an 18-8 alloy (density about 8) with the standard 24-hour period the formula becomes—

$$IPY = \frac{\text{Milligrams lost}}{365 \times \text{area}}$$

'*Special Comments*

It is absolutely necessary that the acid be kept boiling gently (approximately 160°C.) during the test, as acid at a lower temperature will reduce appreciably the corrosion rate. It is recommended that a temperature reading be made at the end of the period, to determine any change in the boiling point during the test.

The reflux condenser should be kept clean and fully inserted in the mouth of the Erlenmeyer flask. Enough water should flow through the condensers to keep them cold to the hand, to prevent leakage out of the top of the condenser. Loss of vapours by using poorly fitted condensers will cause a rapid increase in the acid concentration and its resulting boiling temperature.

Precautions should be taken against the possibility of flask breakage with the consequent spilling of hot acid, and flasks should be inspected for cracks before using. Rubber gloves are advisable when handling the hot acid.

Only phosphoric acid meeting Baker's analyzed quality and ACS standards shall be used. ACS standards are as follows:—

Assay—not less than 86 per cent. H_3PO_4.

Chloride (Cl)—not more than 0·0005 per cent.

Nitrate (NO_3)—to pass test (limit to about 0·0005 per cent.).

Reducing substances (SO_2)—to pass test.

Sulphate (SO_4)—not more than 0·003 per cent.

Volatile acids (as acetic)—not more than 0·0015 per cent.

Alkali and other phosphates—not more than 0·20 per cent. as sulphates.

Arsenic (As)—not more than 0·0002 per cent.

Heavy metals—not more than 0·001 per cent. as lead.

Iron—not more than 0·005 per cent.'

The authors present a considerable amount of data, obtained in their own and other laboratories, confirming the consistency and reliability of the above test.

A later section of the paper deals with the influence of composition of stainless nickel-chromium steel on resistance to corrosion by phosphoric acid: particular attention is given to the beneficial effect of the presence of copper in the steel. Steels containing about 0·2 per cent. or more of copper show appreciably improved resistance to attack, but it is noted that although the copper ions apparently inhibit attack on materials having a chromium content over a certain critical value (about 12 per cent.), they do not exert a protective effect on steel containing less than that amount of chromium. Although the mechanism of the action of copper is not yet fully understood, it is believed that it fortifies the passive film on the surface of the metal.

Following the observation of the influence of copper in the steel, tests were made in which varying amounts of copper ions were added to the phosphoric-acid solution. In this series also a beneficial influence was observed. Experiments with other metallic ions added to the solution (silver, cadmium and tin) showed that only silver exerted an inhibiting action similar to that of copper. Further tests, made to study more closely the inhibiting influence of copper ions, indicated there is a trend in corrosion rate depending on the copper content of the phosphoric-acid solution, as well as on the copper content of the material. With a steel containing about 3 per cent. of copper (Carpenter 20 alloy) approximately 0·0003 per cent. copper is needed in the solution to produce effective inhibiting action, whereas for a material containing only about ¼ per cent. of copper between 0·0005 and 0·001 per cent. copper in the solution will produce the highest degree of corrosion-resistance. It follows that copper-bearing stainless materials will exhibit their highest resistance to corrosion only in service applications in which corrosion products are allowed to accumulate, a fact which to some extent limits the usefulness of the laboratory test described. It is, however, pointed out that such limitation is necessarily inherent in all forms of accelerated corrosion test, and that it serves merely to emphasize the fact that ultimate selection of materials can safely be made only on the basis of service-condition tests.

A table in the paper shows results of some tests made in the authors' laboratories on a wide range of materials, using the standard procedure. It is stated that in the case of the more resistant materials, the test results show good agreement with data published by the Tennessee Valley Authority on the behaviour of various materials in superphosphoric acid at elevated temperatures ('Development of Processes and Equipment for Production of Phosphoric Acid': *T.V.A. Engineering Report No.* 2, 1948).

In discussion, reference was made to the relative value of the phosphoric-acid and the nitric-acid tests as indicative of corrosion-resistance. The nitric-acid test did not reveal any difference in behaviour between materials of varying copper content, but it was more searching than the phosphoric-acid test in discriminating between the effects of different heat-treatments.

Monel Bromine Containers

A. R. JASUTA: 'Victory Over Bromine.' *Reprint from Modern Packaging*, June, 1951. Issued by International Nickel Co., Inc., Oct., 1951; 7 pp.

For the past 30 years commercial demand for bromine has been increasing, and its highly corrosive and toxic nature has, until recently, presented a difficult problem to producers, from the point of view of bulk packaging. Many materials have been tried, and most have proved unsuitable: two types, lead-lined steel and glass, have been successfully used, but each of these has serious shortcomings, which are briefly reviewed in this article.

Until recently the best large-sized container was a lead-lined steel drum. This, however, had many disadvantages. In the U.S.A. the Interstate Commerce Commission limits capacity of this type of container to 10 gallons, and such vessels weigh about 140 lb. and carry only 225 lb. of bromine. Each lead-lined

drum cost about 120 dollars, and a further undesirable feature was that lead contamination of bromine was found to occur. Some years ago the Westvaco Company, after receiving numerous complaints as to the unsatisfactory nature of lead-lined containers, discontinued them, and for a time only 6½-lb. glass bottles were used, packed in wooden containers, each of which carried nine bottles.

Such procedure was, however, obviously unsatisfactory and uneconomic. The Company therefore instituted a comprehensive series of tests on materials potentially suitable for use as containers for large-scale transport. Report of the tests was published in 1949 (*Industrial and Engineering Chemistry*, 1949, vol. 41, Dec., pp. 2792-7; *Nickel Bulletin*, 1950, vol. 23, No. 2, p. 39).

The tests clearly revealed the outstanding superiority of Monel and nickel in resistance to dry bromine, but indicated that they were attacked by wet bromine. This obstacle was subsequently removed by development of a special drying process for treatment of the bromine, and intensive tests were continued, on Monel and nickel, with a view to determining the mechanical suitability of these materials, and the design of drum which would best meet service requirements. In July, 1948, I.C.C. authority had been granted for use of both nickel and Monel drums, and the final selection was a Monel drum of improved design, which has now been in highly successful service for more than a year. Details are given in this publication of the form and other characteristics of the drum, and of the precautions to be taken to prevent access of moisture during loading and unloading of the bromine. The advantages of Monel drums is demonstrated by a tabular comparison of Monel, lead-lined drums, and cased glass bottles. The three types are assessed on the basis of preservation of quality of product handled, safety, cost in handling, transport, etc., ease of cleaning and maintenance, storage space, etc. The comparison is overwhelmingly in favour of the Monel drums, and this conclusion is supported by the reception which has been given to the new container by the bromine-using industry. As a typical example, one customer who formerly purchased bromine in bottles reports that the new drum has made it possible to decrease labour staff engaged in emptying and maintenance by 50 per cent., shifting this labour to more productive work.

Influence of Shape of Component on Atmospheric Corrosion

H. R. COPSON: 'Effect of Specimen Shape on Corrosion in the Atmosphere.' *Corrosion*, 1951, vol. 7, Oct., pp. 335-8.

Since it is well known that rate of corrosion of metals in the atmosphere varies with the nature and amount of pollution present, it is axiomatic that rate of corrosion increases with the amount of contamination actually coming into contact with the object corroded. This variable is controlled not only by the degree of pollution present, but also by the shape and form of the specimen. Although it is obvious that shape must be an important factor in determining the extent of the access of air-borne pollution, this aspect of corrosion has not received much detailed consideration in the literature. The present paper specifically calls attention to it. The views expressed are supported by a number of appropriate illustrations culled from a wide range of atmospheric corrosion-test data, on ferrous and non-ferrous materials exposed in various forms, under conditions involving many types of atmospheric attack.

Data are presented on corrosion effects observed on plain and threaded steel bars, wire and sheet of various non-ferrous materials, and wire-mesh insect screen in non-ferrous metals and alloys. Nickel, nickel-copper alloys of various types, and 80-20 nickel-chromium alloy are among the materials for which data are tabulated in support of the conclusions drawn.

The results show that wire corrodes faster than sheet, because it picks up more of the pollution per unit area. Similarly, open-mesh screen may corrode more rapidly than wire. Specimens occupying any given space will pick up the same amount of pollution and show the same weight loss, but the corrosion rate per unit area will increase or decrease as the surface area of the specimen decreases or increases.

Welding of Stainless Steels by the Aircomatic Process

W. G. BENZ and J. S. SOHN: 'Aircomatic Welding of Austenitic Stainless Steels.' *Welding Jnl.*, 1951, vol. 30, Oct., pp. 911-26.

The authors open with reference to earlier papers in which the basic principles of the Aircomatic process have been described; particular attention is directed to the description by MULLER et al. (*ibid.*, 1950, vol. 29, pp. 458-82: *Nickel Bulletin*, 1950, vol. 23, No. 9, p. 175).

Although most of the data previously reported deal with the application of the method to the welding of aluminium, other materials, such as copper, copper alloys, steel and stainless chromium-nickel steels are now being successfully welded by the Aircomatic method. Some data on conditions for stainless steel were given by Muller (*loc. cit.*).

The present paper reports an investigation carried out to evaluate the properties of stainless-steel welds made by this process. Tensile and bend values, impact strength at several temperatures, and resistance of the welded joints to the acidified-copper-sulphate and the boiling-nitric-acid tests were determined. The plate materials used were of the following types: 304, 304 E.L.C., 310, 316, 321 and 347. The filler wires were of six grades: 308 E.L.C., 308 normal, 310, 316, 321 and 347.

The test results, which are reported in full for the respective series of experiments, show that the properties of the welded joints and of the weld metal contained in them compare favourably with the mechanical strength and corrosion-resistance of welds of similar compositions deposited with Type 300 covered electrodes. The weld metal deposited with the commercial grades of 19-9 chromium-nickel filler wires shows a tensile strength of at least 80,000 p.s.i. (35·75 tons per sq. in.), with elongation values of 40-50 per cent. Transverse guided-bend test bars containing these weld metals withstood bending through

180°. The keyhole Charpy impact-strength values ranged from 34 to 56·3 ft.-lb. at 75°F. (23·8°C.) for weld metal Type 347 (19-9-Nb), and from 16 to 32 at −320°F. (−196°C.) for weld metal Type 308.

The resistance of the weld deposits to corrosion in the nitric-acid and the copper-sulphate/sulphuric acid tests followed the trend general in the same types of weld metal deposited from covered electrodes. As-deposited weld metal of Types 308 E.L.C., 308 normal and 347 proved satisfactory in both tests; Type 310 behaved well in the nitric-acid solution but not under the copper-sulphate test. Type 321 showed borderline corrosion in the nitric-acid test, but satisfactory resistance in the copper-sulphate solution. Type 316 gave unsatisfactory resistance in the nitric-acid test.

Plug Welding Technique in Fabrication of Stainless-Clad Mixing Bowls

W. M. DAVIS: 'Plug Welding Technique in Clad Lining Dough Mixer Bowls.' *Welding Jnl.*, 1951, vol. 30, Sept., pp. 829-31.

This article gives a well illustrated step-by-step description of methods developed for plug-welding stainless-clad sheet to heavy grey-iron castings used as end members on a large dough-mixing bowl. It is stated that the new procedure has saved 30 per cent. in assembly time, and that although more than 1,000 models employing this type of construction have already been put into service no complaint has been received on any score. The welded stainless-clad bowl has the further great advantage of being easy to clean to strict sanitary standards, and is thus more economical to operate.

The bowls described are mixer drums used on a 50 h.p. mixing machine. The drum holds 1,600 lb. of dough, which is mixed by agitator blades on a Monel shaft, turning on bearings in the end castings.

Production of Patina on Nickel and Nickel Alloys

See abstract on p. 255.

'Whiskers' on Metal Surfaces

K. G. COMPTON, A. MENDIZZA and S. M. ARNOLD: 'Filamentary Growths on Metal Surfaces—'Whiskers'.' *Corrosion*, 1951, vol. 7, Oct., pp. 327-34.

This report, from the Bell Telephone Laboratories, Inc., gives preliminary results of an investigation of the occurrence of 'whiskers', such as the filamentary growths which developed between the leaves of cadmium-plated variable air condensers during World War II. The mechanism of the growth of whiskers, and the conditions which cause such growths, are being studied on a wide variety of metals and electrodeposited metallic coatings. Nickel and electrodeposited nickel coatings are among the materials included in the tests.

The paper describes test methods and gives a considerable amount of information on observations made to date: it is illustrated by photographs of 'whiskering' in tin- and cadmium-plated steel, silver-plated steel, and solid zinc, aluminium alloy and tin. Nickel is among the materials which up to the present have not, under the test conditions, developed any sign of the defect.

Although the mechanism of whisker growth has not yet been fully elucidated, the information already available is considered to justify the following conclusions:—

Whisker growths are not limited to electrodeposited coatings, and may be found on solid metals as well as on surfaces metal-coated by various methods. The growths may develop in an environment in which there is relatively low humidity and in which there are, at most, only traces of organic material.

The whiskers are not compounds but are metallic filaments in the form of single or twinned crystals.

Bart 'Lectroclad' Process for Internal Nickel Plating of Pipe

See abstract on p. 255.

Binders for 1951 and 1952 Nickel Bulletins are now available. If you will indicate the particular one you require, we shall be pleased to send you this free of charge.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

SUBJECT INDEX TO VOLUME 24

The Index to The Nickel Bulletin for 1951 follows the form used in 1950, a consolidated list compiled from the sectional contents lists of the individual issues.

Within the sections normally used (General, Nickel, Electrodeposition, etc.) the items are *broadly classified* in appropriate sub-sections, within which the items are entered *in the order of their appearance in the Bulletin.* The only exception to this order is the grouping of the page numbers of serial items, and of items of very closely similar subject matter, and the arrangement in alphabetical order of the items in the 'General' section.

The individual abstracts are, in most cases, entered under the substantive titles used when they were originally reported. Leading articles and data sheets are listed separately, and are also shown in the appropriate sections: in the sections they are differentiated from abstracts by an asterisk at the beginning of the title.

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